

**PRELIMINARY SURVEY REPORT:
PRE-INTERVENTION QUANTITATIVE RISK FACTOR ANALYSIS
FOR SHIP CONSTRUCTION PROCESSES**

at

**LITTON INGALLS SHIPBUILDING SHIPYARD,
Pascagoula, Mississippi**

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PLANT SURVEYED:	Litton Ingalls Shipbuilding shipyard, Litton Ship Systems, 1000 Access Road, Pascagoula, Mississippi 39567.
SIC CODE:	3731
SURVEY DATE:	March 20-21, 2000
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ABSTRACT

A pre-intervention quantitative risk factor analysis was performed at various shops and locations within Litton Ship Systems, Litton Ingalls Shipbuilding shipyard in Pascagoula, Mississippi as a method to identify and quantify risk factors that workers may be exposed to in the course of their normal work duties. This survey was conducted as part of a larger project, funded through Maritech Advanced Shipbuilding Enterprise and the U.S. Navy, to develop projects to enhance the commercial viability of domestic shipyards. Several operations were identified for further analysis including: abrasive blasting, hatch assembly, pipe welding, subassembly grinding, and on-board cable pulling. The application of exposure assessment techniques provided a quantitative analysis of the risk factors associated with the individual tasks. Possible engineering interventions to address these risk factors for each task are briefly discussed.

I. INTRODUCTION

IA. BACKGROUND FOR CONTROL TECHNOLOGY STUDIES

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency in occupational safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposures to potential chemical and physical hazards.

Since 1976, NIOSH has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of the completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies had been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

IB. BACKGROUND FOR THIS STUDY

The domestic ship building, ship repair, and ship recycling industries have historically had much higher injury/illness incidence rates than those of general industry, manufacturing, or construction. For 1998, the last year available, the Bureau of Labor Statistics reported that shipbuilding and repair (SIC 3731) had a recordable injury/illness incidence rate of 22.4 per 100 full-time employees (FTE), up from 21.4 in 1997. By contrast, in 1998, the manufacturing sector reported a rate of 9.7 per 100 FTE, construction reported a rate of 8.8 per 100 FTE, and all industries reported a rate of 6.7 injuries/illnesses per 100 FTE. When considering only lost workday cases, for 1998, shipbuilding and repair had an incidence rate of 11.5 per 100 FTE, compared to manufacturing at 4.7, construction at 4.0, and all industries at 3.1 lost workday injuries/illnesses per 100 FTE.

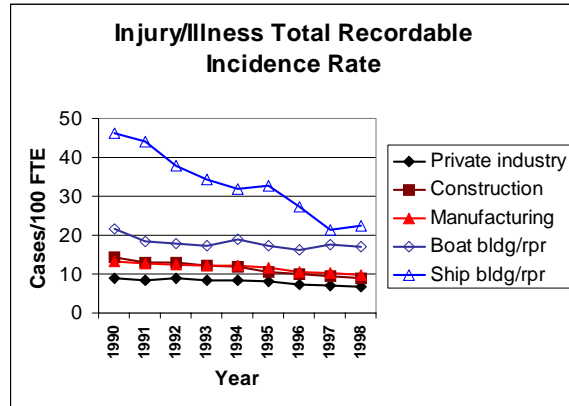


Figure 1. Injury/Illness Total Recordable Incidence Rate

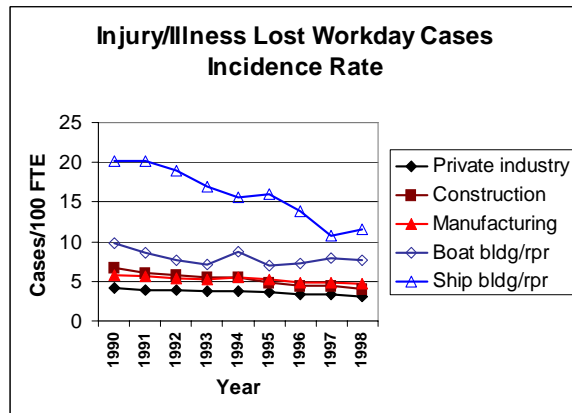


Figure 2. Injury/Illness Lost Workday Cases Incidence Rate

When comparing shipbuilding and repairing to the manufacturing sector for injuries and illnesses to specific parts of the body resulting in days away from work, for the year 1997, shipbuilding is significantly higher in a number of instances. For injuries and illnesses to the trunk including the back and shoulder, shipbuilding reported an incidence rate of 207.7 cases per 10,000 FTE, compared to manufacturing at 82.1 cases. For injuries and illnesses solely to the back, shipbuilding reported 111.1 cases per 10,000 FTE, compared to manufacturing's incidence rate of 52.2 cases. For the lower extremity, shipbuilding reported 145.0 cases per 10,000 FTE compared to manufacturing at 40.8 cases. For upper extremity injuries and illnesses, shipbuilding reported an incidence rate of 92.2 cases per 10,000 FTE while manufacturing reported 73.4 cases.

When comparing shipbuilding and repairing to the manufacturing sector for injuries and illnesses resulting in days away from work, for the year 1997, by nature of injury, shipbuilding is significantly higher in a number of categories. For sprains and strains, shipbuilding reported an

incidence rate of 237.9 cases per 10,000 FTE, compared to manufacturing's incidence rate of 91.0 cases. For fractures, shipbuilding reported 41.7 cases per 10,000 FTE, compared to manufacturing at 15.8 cases. For bruises, shipbuilding reported 61.3 cases per 10,000 FTE, compared to manufacturing at 21.5 cases. The median number of days away from work for shipbuilding and repairing is 12 days, compared to manufacturing and private industry's median of 5 days.

Beginning in 1995 the National Shipbuilding Research Program began funding a project looking at the implementation of ergonomic interventions at a domestic shipyard as a way to reduce Workers' Compensation costs and to improve productivity for targeted processes. That project came to the attention of the Maritime Advisory Committee for Occupational Safety and Health (MACOSH), a standing advisory committee to the Occupational Safety and Health Administration (OSHA). The National Institute for Occupational Safety and Health (NIOSH) began an internally funded project in 1997 looking at ergonomic interventions in new ship construction facilities. In 1998, the U.S. Navy decided to fund a number of research projects looking to improve the commercial viability of domestic shipyards, including projects developing ergonomic interventions for various shipyard tasks or processes. Project personnel within NIOSH successfully competed in the project selection process. The Institute currently receives external project funding from the U.S. Navy through an organization called Maritech Advanced Shipbuilding Enterprise, a consortium of major domestic shipyards.

Shipyards participating in this project will receive an analysis of their injury/illness data, will have at least one ergonomic intervention implemented at their facility, and will have access to a website documenting ergonomic solutions found throughout the domestic maritime industries. The implementation of ergonomic interventions in other industries has resulted in decreases in Workers' Compensation costs, and increases in productivity.

Researchers have identified seven participating shipyards and have analyzed individual shipyard recordable injury/illness databases. Ergonomic interventions will be implemented in each of the shipyards and intervention follow-up analysis will be completed following a six- to nine-month period. A series of meetings and a workshop to document the ergonomic intervention program will be held by the end of March 2001.

IC. BACKGROUND FOR THIS SURVEY

Litton Ship Systems, Litton Ingalls Shipbuilding facility was selected for a number of reasons. It was decided that the project should look at a variety of yards based on product, processes and location. Litton Ship Systems is one of the nation's leading full service systems companies for the design, engineering, construction and life cycle support of major military and commercial vessels. Litton Ingalls Shipbuilding builds, repairs and overhauls military vessels including AEGIS class guided missile destroyers and multipurpose amphibious assault ships. In addition, Litton Ingalls Shipbuilding also constructs oil rigs and has begun construction on the first domestically built commercial cruise ships in over forty years. Litton Ingalls Shipbuilding

facility is considered to be a large shipyard.

II PLANT AND PROCESS DESCRIPTION

IIA. INTRODUCTION

Plant Description: The Litton Ingalls Shipbuilding shipyard is located on the Gulf of Mexico in Pascagoula, Mississippi. The shipyard consists of two neighboring facilities. The primary, or West Bank, facility encompasses 600 acres, including five major module assembly areas or lines. In 1988, approximately 181,000 square feet of the yard's slab area was brought under roof to facilitate pre-outfitting operations. Construction is underway to roughly double the amount of square footage under roof. Vessels are currently launched from a drydock that is about 850 feet in length and 174 feet wide. New sections are being built at the shipyard to lengthen the drydock to accommodate longer vessels. Currently, approximately 4,700 feet of berthing space is available but this is also being expanded due to new contracts. A 600-ton capacity crane is being built to accommodate larger blocks or units.

Corporate Ties: Litton Ingalls Shipbuilding is a division of Litton Industries and a Litton Ship Systems Company. Litton Ship Systems also operates Litton Avondale Industries, a shipyard near New Orleans, Louisiana.

Products: Litton Ingalls Shipbuilding, as of March 1, 2000, is under contract to the U.S. Navy to deliver thirteen AEGIS class guided missile destroyers and one multipurpose amphibious assault ship. Additionally, the shipyard is overhauling and modernizing two frigates for the Venezuelan Navy. Contracts have been signed to build two 1,900-passenger, 840-foot luxury cruise ships for the Hawaiian Islands market, the first large cruise ships to be built in this country in over forty years.

Age of Plant: Litton Ingalls Shipbuilding original, or East Bank, facility has been in operation since 1938. The main, or West Bank, facility was opened in 1970 and is currently undergoing a major capital expenditure program to upgrade facilities.

Number of Employees, etc: As of the date of the survey, the Litton Ingalls Shipbuilding facility employed a total of 10,200 workers. Of this number, 6,823 are considered production workers.

IIB. PROCESS DESCRIPTION

Steelyard -- Steel is delivered to the facility by truck, rail and barge and is stored in an outside storage yard serviced by multiple overhead and mobile tracked cranes.

Surface Preparation -- Steel plate and shaped steel are moved from the supply yard by crane into a surface preparation area via large automated conveyors. Steel is abrasive blasted to remove any

rust or mill residue. Primer paint is applied which coats the steel with an inorganic zinc coating to inhibit rusting.

Plate Shop -- Steel plate is cut to size using large computer controlled plasma cutting water tables. Smaller shapes are also cut using an automated process with standard burning torches being used in tandem. Steel plates are moved on and off of water tables via overhead magnet cranes. Some shapes/pieces are cut at the shears or punched at the punch presses.

Subassembly -- Steel shapes are pieced together and welded to form a variety of sub-assemblies. Individual foundations, ships doors and hatches, light trays, etc. are then transferred to the Assembly Building for installation/assembly into ship units. Smaller subassemblies are joined to create bigger units.

Assembly -- The majority of assembly is performed on one of the main assembly lines. These assembly lines are currently outside and form a direct line to the actual launching area. This is where units are assembled and outfitted with various structures. Some units are inverted to assist with the installation of decks and inner bottom sections. Some piping and ventilation work is also performed at this stage of the fabrication. Once initial assembly is completed the units are blasted and painted and moved further down the production line.

Final Assembly -- The individual units of the ship are welded together to form the hull and house sections. Once this has been completed and the entire hull is water tight, the vessel is placed into the water for further outfitting. Cable pulling, tank painting, piping and ventilation runs, etc. are worked on extensively at this stage of fabrication.

Outfitting -- The installation of propulsion, electrical, HVAC and other systems is begun after sub-assembly and continues well after the vessel is launched.

Painting -- Vessels are painted to customer specifications prior to launch.

IIC. POTENTIAL HAZARDS

Major Hazards: Awkward postures, multiple manual material handling issues including lifting, carrying, pushing and pulling heavy objects, confined space entry, welding fumes, UV radiation from welding, paint fumes, hand/arm segmental vibration.

III. METHODOLOGY

A variety of exposure assessment techniques were implemented where deemed appropriate to the job task being analyzed. The techniques used for analysis include: 1) the Rapid Upper Limb Assessment (RULA); 2) the Strain Index; 3) a University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders; 4) the OVAKO Work Analysis System (OWAS); 5) a Hazard

Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling; 6) the NIOSH Lifting Equation; 7) the University of Michigan 3D Static Strength Prediction Model; and 8) the PLIBEL method.

The Rapid Upper Limb Assessment (RULA) (McAtamney and Corlett, 1993) is a survey method developed to assess the exposure of workers to risk factors associated with work-related upper limb disorders. On using RULA, the investigator identifies the posture of the upper and lower arm, neck, trunk and legs. Considering muscle use and the force or load involved, the investigator identifies intermediate scores which are cross-tabulated to determine the final RULA score. This final score identifies the level of action recommended to address the job task under consideration.

The Strain Index (Moore and Garg, 1995) provides a semiquantitative job analysis methodology that appears to accurately identify jobs associated with distal upper extremity disorders versus other jobs. The Strain Index is based on ratings of: intensity of exertion, duration of exertion, efforts per minute, hand and wrist posture, speed of work, and duration per day. Each of these ratings is translated into a multiplier. These multipliers are combined to create a single Strain Index score.

The University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders (Lifshitz and Armstrong, 1986) allows the investigator to survey a job task with regard to the physical stress and the forces involved, the upper limb posture, the suitability of the workstation and tools used, and the repetitiveness of a job task. Negative answers are indicative of conditions that are associated with the development of cumulative trauma disorders.

The OVAKO Work Analysis System (OWAS) (Louhevaara and Suurnäkki, 1992) was developed to assess the quality of postures taken in relation to manual materials handling tasks. Workers are observed repeatedly over the course of the day and postures and forces involved are documented. Work postures and forces involved are cross-tabulated to determine an action category which recommends if, or when, corrective measures should be taken.

The NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling (Waters and Putz-Anderson, 1996) is an example of a simple checklist that can be used as a screening tool to provide a quick determination as to whether or not a particular job task is comprised of conditions that place the worker at risk of developing low back pain.

The NIOSH Lifting Equation (Waters et al, 1993) provides an empirical method to compute the recommended weight limit for manual lifting tasks. The revised equation provides methods for evaluating asymmetrical lifting tasks and less than optimal hand to object coupling. The equation allows the evaluation of a greater range of work durations and lifting frequencies. The equation also accommodates the analysis of multiple lifting tasks. The Lifting Index, the ratio of load lifted to the recommended weight limit, provides a simple means to compare different lifting tasks.

The University of Michigan 3D Static Strength Prediction Program (University of Michigan, 1997) is a useful job design and evaluation tool for the analysis of slow movements used in heavy materials

handling tasks. Such tasks can best be analyzed by describing the activity as a sequence of static postures. The program provides graphical representation of the worker postures and the materials handling task. Program output includes the estimated compression on the L5/S1 vertebral disc and the percentage of population capable of the task with respect to limits at the elbow, shoulder, torso, hip, knee and ankle.

The PLIBEL method (Kemmlert, 1995) is a checklist method that links questions concerning awkward work postures, work movements, design of tools and the workplace to specific body regions. In addition, any stressful environmental or organizational conditions should be noted. In general, the PLIBEL method was designed as a standardized and practical assessment tool for the evaluation of ergonomic conditions in the workplace.

IIIA. ABRASIVE BLASTING WORKER IN STEELYARD

IIIA1. Abrasive Blasting Process

Steel structures are blasted by employees utilizing specialized blast guns which propel steel shot or silica sand at an item at up to 100 psi, thus removing all foreign debris and pitting the steel which provides for better adherence of the paint coating to the steel. Blasters are completely covered with protective clothing including positive pressure respirators. Blast hose is heavy and difficult to bend around and manipulate in tight areas. Moderate force must be exerted to hold blast nozzle as the energy created by the steel shot being propelled at a high velocity raises the nozzle. This task is somewhat similar to the forces exerted by firefighters handling large hoses.

1. Figure 3 depicts the blasting of a steel beam below knee height. Trunk is in good posture with some forward neck flexion.



Figure 3. Abrasive Blaster Blasting Material Below Knee Height

2. When material is at or slightly higher than waist height, posture can be affected. In Figure 4, a slight forward trunk posture with slight axial rotation is assumed.



Figure 4. Abrasive Blaster Adjusting Tools

3. When blasting tasks require the gun be held at or above mid chest height, it results in poor posture of the arm/hand operating the nozzle. Note the method employed by blasters to control hose in Figure 5 below. It is bent and held in this position by applying an inward force with elbow and upper arm hugging the hose to the torso. This effort is sustained throughout the blast cycle.



Figure 5. Abrasive Blaster Blasting Material Above Waist Height

4. Once area has been blasted, employee must move equipment to next blast site. This involves moving hoses, airlines, etc as depicted in Figure 6.



Figure 6. Abrasive Blaster Re-Positioning Material to be Blasted

IIIA2. Abrasive Blasting Ergonomic Risk Factors

Blasters exert high levels of force to control and hold the blast nozzles when engaged. This force is applied at a constant level. The force required to control blast nozzle is increased due to the wearing of heavy gloves and awkward postures of the wrist. Some forward flexion of the neck is performed when working below knee height and neck extension is performed when blasting overhead. Forward bent posture is also common. When blasting in tanks, kneeling and crawling is performed. This is a physically demanding job.

IIIA3. Ergonomic Analysis of Abrasive Blasting Workers in Steelyard

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the abrasive blasting workers in the steelyard. A Rapid Upper Limb Assessment was conducted for the abrasive blasting worker (Table 1). Analyses of six sub-tasks with unique postures and a composite task analysis resulted in a variety of ratings. The sub-task of blasting below knee level resulted in a rating of 7, “investigate and change immediately,” on a scale of 1 to 7. The sub-task of blasting above waist level resulted in a rating of 6, “investigate further and change soon.” Three sub-tasks, blasting at knee level, repositioning leads and adjusting posture, each resulted in a rating of 3 or 4, “investigate further.” The final sub-task, resting, rated a 2, “acceptable.”

A Strain Index analysis was performed for the abrasive blasting worker (Table 2) with the following results:

- 1) the Intensity of Exertion was rated as “Hard” and given a multiplier score of 6.0 on a scale of 1 to 13
- 2) the Duration of the task was rated as 50 - 79 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0

- 3) the Efforts per Minute were noted to be static, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
- 4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
- 5) the Speed of Work was rated as “Normal,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
- 6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.0 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 54. An SI score between 31 and 60 is correlated to an incidence rate of about 106 distal upper extremity injuries per 100 FTE. Therefore, the Strain Index indicates that this task puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the abrasive blasting worker task (Table 3), of the 21 possible responses, fifteen were negative and seven were positive (one answered both). Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the abrasive blasting worker task (Table 4), “corrective measures as soon as possible” were suggested for blasting below or at knee level and repositioning the body and hoses. Adjusting the blaster position resulted in the need for “corrective measures in the near future.”

The PLIBEL checklist for the abrasive blasting worker task (Table 5) reports a moderate percentage (45.5 - 53.8 %) of risk factors present for the upper extremities and back. Several environmental and organizational modifying factors are present as well.

IIIB. CABLE PULLING ONBOARD VESSEL

IIIB1. Cable Pulling Process

Multiple lines of cable varying in length, size and weight are pulled by hand throughout areas of the ship. The larger cable pulls are performed by workers in groups numbering as high as 20. The size of the crew is largely dependent on the size, length, routing and final location of cable. Cable pulling in a variety of postures and with varying sizes of cable was analyzed. Cable runs are located overhead, along bulkheads, and below deck plate level. All cable is secured into cable trays and tagged whenever passing through a bulkhead or deck. When running from one deck to another, the cable passes through oval openings or transits, which are later packed to assure an air- and water-tight seal.

Installing cable requires the workers to assume a variety of postures. In Figure 7, cable is being pulled at waist height. In Figure 8, the cable run is below deck and is between knee and foot level. Figures 9 through 12 show the worker pulling smaller cable horizontally through a cable tray overhead. Figures 13 through 15 show a worker pulling down on large diameter cable, weighing about 7 pounds per linear foot. Figures 16 through 19 show a worker pushing large diameter cable upward to pass through a transit or opening between decks.



Figure 7. Cable Puller Standing, Pulling 2-3" Diameter Cable Horizontally



Figure 8. Cable Puller Squatting, Pulling 2-3" Diameter Cable Horizontally at Ankle Height



Figure 9. Cable Puller Holding 1.5" Diameter Cable Overhead Prior to Pull



Figure 10. Cable Puller Pulling 1.5" Diameter Cable Horizontally Overhead



Figure 11. Close-up of Cable Puller Pulling 1.5" Diameter Cable Horizontally Overhead



Figure 12. Cable Puller (1.5" Diameter) Resting, Arm Still Overhead



Figure 13. Cable Puller Pulling 2-3" Diameter Cable Downward, Beginning of Pull



Figure 14. Cable Puller Pulling 2-3" Diameter Cable Downward, Mid Pull



Figure 15. Cable Puller Holding 2-3" Diameter Cable Overhead, Tensed to Pull Down



Figure 16. Cable Puller Pushing-Up 2-3" Diameter Cable, Body Extended Near End of Push



Figure 17. Cable Puller Holding 2-3" Diameter Cable, Waiting to Push -Up



Figure 18. Cable Puller Crouching, Beginning to Push-Up 2-3" Diameter Cable



Figure 19. Cable Puller Taking a Well-Deserved Break

IIIB2. Ergonomic Risk Factors of Cable Pullers

Multiple risk factors were observed during the pulling process. Forceful exertions are common when handling the larger cable. This is significantly magnified due to postures assumed while engaged in the pulling process. When pulling cable below deck plate level, forward neck and trunk flexion is common. This is due to the location of cable trays and the specific route of the cable run. These postures can be static in nature with force being exerted while at a biomechanical disadvantage.

When pulling cable overhead, significant moment loads are placed on the shoulder and low back. Shoulder flexion and neck extension is common when pulling cable overhead with force being exerted at arm's length. This is a very physically demanding job with regard to the amount of force exerted.

IIIB3. Ergonomic Analysis of Cable Pullers Onboard Vessel Cable Pullers (2-3" diameter, horizontal pull)

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the shipboard cable pullers (2-3" diameter, horizontal pull). A Rapid Upper Limb Assessment was conducted for these workers (Table 6), analyzing four sub-tasks with unique postures and forces. One of the four subtasks, pulling cable horizontally below knee level, scored a 7 (investigate and change immediately) on a scale of 1 to 7. Another subtask, holding cable below knee level/ waiting for signal, resulted in a score of 6 (investigate further and change soon). Another subtask, pulling cable horizontally above knee level, resulted in a score of 4 (investigate further). The final subtask of resting was the only one deemed "acceptable" with a score of two out of seven.

A Strain Index analysis was performed for the shipboard cable pullers (2-3" diameter, horizontal pull) (Table 7) with the following results:

- 1) the Intensity of Exertion was rated as "Very Hard" and given a multiplier score of 9 on a scale of 1 to 13
- 2) the Duration of the task was rated as 21 % of the task cycle, resulting in a multiplier of 1.0 on a scale of 0.5 to 3.0
- 3) the Efforts per Minute were noted to be 6, resulting in a multiplier of 1.0 on a scale of 0.5 to 3.0
- 4) the Hand/Wrist posture was rated as "Bad," resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0
- 5) the Speed of Work was rated as "Fair," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
- 6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 18. An SI score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the shipboard cable puller (2-3" diameter, horizontal pull) at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the shipboard cable puller (2-3" diameter, horizontal pull) (Table 8), of the 14 possible responses, nine were negative and five were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the shipboard cable puller (2-3" diameter, horizontal pull) (Table 9), corrective measures were suggested for the specific sub-tasks of pulling cable horizontally below knee level, holding cable below knee level/ waiting for signal, and pulling cable horizontally above knee level.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the shipboard cable pulling (2-3" diameter, horizontal pull) subtask of pulling cable below knee level (Table 10). Analysis of this sub-task resulted in estimated disc compression loads at the L5/S1 disc of 133 pounds, which is well below the NIOSH Recommended Compression Limit of 770 pounds.

The PLIBEL checklist for the shipboard cable puller (2-3" diameter, horizontal pull) (Table 11) reports a high percentage (82 %) of risk factors present for the elbows, forearms, and hands. Moderate percentages of risk factors present for the neck, shoulder, upper back, feet, knees and hips (~ 50 %), and low back (~ 48%) were also reported. Several environmental and organizational modifying factors are present as well.

Cable Pullers (1-2" diameter, overhead horizontal pull)

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the shipboard cable pullers (1-2" diameter, overhead). A Rapid Upper Limb Assessment was conducted for the these workers (Table 12), analyzing three sub-tasks with unique postures and forces. Two of three subtasks, pulling cable overhead and holding cable over head/ waiting for signal, scored at least 5's (investigate further and change soon) on a scale of 1 to 7. The final subtask of resting/ waiting for signal scored a 3 (investigate further).

A Strain Index analysis was performed for the shipboard cable pullers (1-2" diameter, overhead) (Table 13) with the following results:

- 1) the Intensity of Exertion was rated as "Hard" and given a multiplier score of 6 on a scale of 1 to 13
- 2) the Duration of the task was rated as 30 % of the task cycle, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
- 3) the Efforts per Minute were noted to be 12.5, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
- 4) the Hand/Wrist posture was rated as "Bad," resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0
- 5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
- 6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 27. An SI score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the shipboard cable puller (1-2" diameter, overhead) at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the shipboard cable puller (1-2" diameter, overhead) (Table 14), of the 13 possible responses, seven were negative and six were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the shipboard cable puller (1-2" diameter, overhead) (Table 15), no corrective measures were suggested for any of the specific sub-tasks.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the shipboard cable pulling (1-2" diameter, overhead) subtask of pulling cable overhead (Table 10). Analysis of this sub-task resulted in estimated disc compression loads at the L5/S1 disc of 636 pounds, which is still below the NIOSH Recommended Compression Limit of 770 pounds.

The PLIBEL checklist for the shipboard cable puller (1-2" diameter, overhead) (Table 17) reports a very high percentage (91 %) of risk factors present for the elbows, forearms, and hands. A moderate percentage of risk factors present for the neck, shoulder, and upper back (~ 50 %) was also reported. Several environmental and organizational modifying factors are present as well.

Cable Pullers (2-3" diameter, downward pull)

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the shipboard cable pullers (2-3" diameter, downward pull). A Rapid Upper Limb Assessment was conducted for these workers (Table 18), analyzing three sub-tasks with unique postures and forces. One of the three subtasks, pulling cable down, scored a 7 (investigate and change immediately) on a scale of 1 to 7. The two other subtasks, resting and holding cable/ waiting for signal, scored 3's (investigate further).

A Strain Index analysis was performed for the shipboard cable pullers (2-3" diameter, downward pull) (Table 19) with the following results:

- 1) the Intensity of Exertion was rated as "Near Maximal" and given a multiplier score of 13 on a scale of 1 to 13
- 2) the Duration of the task was rated as 22 % of the task cycle, resulting in a multiplier of 1.0 on a scale of 0.5 to 3.0
- 3) the Efforts per Minute were noted to be 12 resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
- 4) the Hand/Wrist posture was rated as "Bad," resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0
- 5) the Speed of Work was rated as "Fast," resulting in a multiplier of 1.5 on a scale of 1.0 to 2.0
- 6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 58.5. An SI score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the shipboard cable puller (2-3" diameter, downward pull) at a greatly increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the shipboard cable puller (2-3" diameter, downward pull) (Table 20), of the 13 possible responses, eight were negative and five were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the shipboard cable puller (2-3" diameter, downward pull) (Table 21), corrective measures were suggested the specific sub-task of pulling cable down.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the shipboard cable pulling (2-3" diameter, downward pull) subtask of pulling cable down (Table 22). Analysis of this sub-task resulted in estimated disc compression loads at the L5/S1 disc of 215 pounds, which is well below the NIOSH Recommended Compression Limit of 770 pounds.

The PLIBEL checklist for the shipboard cable puller (2-3" diameter, downward pull) (Table 23) reports a high percentage (64 %) of risk factors present for the elbows, forearms, and hands. A lower percentage of risk factors present for the neck, shoulder, and upper back (~ 42 %) was also reported. Several environmental and organizational modifying factors are present as well.

Cable Pullers (2-3" diameter, upward push)

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the shipboard cable pullers (2-3" diameter, upward push). A Rapid Upper Limb Assessment was conducted for these workers (Table 24), analyzing three sub-tasks with unique postures and forces. One of the three subtasks, feeding/ pushing cable upwards, scored a 7 (investigate and change immediately) on a scale of 1 to 7. The two other subtasks, resting and holding cable/ waiting for signal, scored at least 3's (investigate further).

A Strain Index analysis was performed for the shipboard cable pullers (2-3" diameter, upward push) (Table 25) with the following results:

- 1) the Intensity of Exertion was rated as "Near Maximal" and given a multiplier score of 13 on a scale of 1 to 13
- 2) the Duration of the task was rated as 21 % of the task cycle, resulting in a multiplier of 1.0 on a scale of 0.5 to 3.0
- 3) the Efforts per Minute were noted to be 10.4 resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
- 4) the Hand/Wrist posture was rated as "Bad," resulting in a multiplier of 2.0 on a scale of 1.0 to 3.0

- 5) the Speed of Work was rated as “Fast,” resulting in a multiplier of 1.5 on a scale of 1.0 to 2.0
- 6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 58.5. An SI score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the shipboard cable puller (2-3" diameter, upward push) at a greatly increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the shipboard cable puller (2-3" diameter, upward push) (Table 26), of the 13 possible responses, eight were negative and five were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the shipboard cable puller (2-3" diameter, upward push) (Table 27), corrective measures were suggested the specific sub-task of feeding/ pushing cable upwards.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the shipboard cable pulling (2-3" diameter, upward push) subtask of pushing cable up (Table 28). Analysis of this sub-task resulted in estimated disc compression loads at the L5/S1 disc of 813 pounds, which exceeds the NIOSH Recommended Compression Limit of 770 pounds. Thus, the 2-3" diameter, upward push cable pull is the only cable pull noted to exceed this limit, which indicates that this task puts the worker at an increased risk of low back injury.

The PLIBEL checklist for the shipboard cable puller (2-3" diameter, upward push) (Table 29) reports a high percentage (64 %) of risk factors present for the elbows, forearms, and hands. A lower percentage of risk factors present for the neck, shoulder, and upper back (~ 50 %) was also reported. Several environmental and organizational modifying factors are present as well.

IIIC. PIPE WELDING IN SHOP

IIIC1. Pipe Welding Process

A certain amount of assembly of piping systems is conducted in the shop area of the shipyard prior to pre-outfitting the unit on land. Pipe positioning units are provided to allow the welder to position the pipe in whichever attitude is necessary to make the weld easiest to complete. Figure 20 shows a welder positioning a pipe in the unit. Figure 21 shows a welder re-positioning the pipe subassembly in the positioning unit. In Figure 22, the welder is adjusting the position of the pipe in order to visually inspect the weld quality. Figure 23 shows the welder installing another

pipe subassembly in the positioner. Figure 24 illustrates the welder in a flexed posture despite having the ability to adjust the positioner and pipe subassembly to any attitude.



Figure 20. Welder Positioning Piece to be Welded



Figure 21. Welder Changing Position



Figure 22. Welder Inspecting Weld Bead, Piece Position



Figure 23. Welder Gathering Supplies



Figure 24. Welder Welding Piece in Flexed Posture Despite Positioner

IIIC2. Ergonomic Risk Factors of Pipe Welders

Pipe welders in the shop area do not have to assume the constrained and awkward postures of pipe welders onboard vessels completing the pipe assemblies. There is manual handling of the pipe subassemblies to position them into the units, however, the subassemblies are relatively light, usually no more than thirty pounds. Despite the capabilities of the pipe positioner, the welder may assume an awkward posture with flexed torso and neck and flexion and ulnar deviation of the wrist holding the welding stick and stinger.

IIIC3. Ergonomic Analysis of Pipe Welders in Shop

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the pipe welders (using positioners). A Rapid Upper Limb Assessment was conducted for these workers (Table 30), analyzing five sub-tasks with unique postures and forces. One of the five subtasks, welding standing, scored a 7 (investigate and change

immediately) on a scale of 1 to 7. All other subtasks, inspecting welding, adjusting positioner, hanging body position, and getting supplies, scored at least 3's (investigate further).

A Strain Index analysis was performed for the pipe welders (using positioners) (Table 31) with the following results:

- 1) the Intensity of Exertion was rated as “Somewhat Hard” and given a multiplier score of 3 on a scale of 1 to 13
- 2) the Duration of the task was rated as 48 % of the task cycle, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
- 3) the Efforts per Minute were noted to be nearly static (due to welding) resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
- 4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
- 5) the Speed of Work was rated as “Fair,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
- 6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 20.3. An SI score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the pipe welders (using positioners) at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the pipe welders (using positioners) (Table 32), of the 21 possible responses, eight were negative and thirteen were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the pipe welders (using positioners) (Table 33), corrective measures were suggested the specific sub-tasks of welding standing and inspecting welds.

The PLIBEL checklist for the pipe welders (using positioners) (Table 34) reports low percentages of risk factors present for the neck, shoulder, and upper back (~ 39 %) and elbows, forearms, and hands (~ 37 %). A few environmental and organizational modifying factors are present as well.

IIID. PANEL LINE GRINDERS

IIID1. Panel Line Grinding Process

In the panel line, horizontal and vertical stiffeners are welded to steel plate to create subassemblies. This requires the worker to use a variety of tools including welding units and

pneumatic grinders and needle guns (see Figure 25). The position of the stiffeners is marked on the steel plate according to the blueprints. Then the stiffeners are placed along the marked pattern and held in place by a co-worker while being tack welded. A final complete seam weld is placed to secure the stiffener to the plate. Then grinders or needle guns are used to smooth out the weld and any weld splatter (Figures 26 and 27). Once the subassemblies are completed, they are combined into blocks or units.



Figure 25. Panel Line Grinder Changing Tools



Figure 26. Panel Line Grinder Grinding



Figure 27. Panel Line Grinder Using Needle Gun

IIID2. Ergonomic Risk Factors of Panel Line Grinders

Workers quite frequently are working at floor level, resulting in flexed torsos and necks. Additional strain is placed on the knees and hips due to this posture. The use of pneumatic or electric tools exposes the worker to hand-arm or segmental vibration.

IIID3. Ergonomic Analysis of Panel Line Grinders

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the panel line grinders. A Rapid Upper Limb Assessment was conducted for the these workers (Table 35), analyzing four sub-tasks with unique postures and forces. Two of the four subtasks, grinding surface and using needlegun, scored 7's (investigate and change immediately) on a scale of 1 to 7. Another subtask, changing tool, scored a 3 (investigate further). The final subtask of repositioning tool/ body was deemed acceptable with a score of 2.

A Strain Index analysis was performed for the panel line grinders (Table 36) with the following results:

- 1) the Intensity of Exertion was rated as “Hard” and given a multiplier score of 6 on a scale of 1 to 13
- 2) the Duration of the task was rated as 58 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
- 3) the Efforts per Minute were noted to be nearly static (due to grinding) resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
- 4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
- 5) the Speed of Work was rated as “Fair,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
- 6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a

multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 54. An SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the panel line grinders at a greatly increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the panel line grinders (Table 37), of the 22 possible responses, fifteen were negative and seven were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the panel line grinders (Table 38), corrective measures were strongly suggested for the specific sub-tasks of grinding surface and using needlegun. Corrective measures for the subtask of changing tool were also suggested.

The PLIBEL checklist for the panel line grinders (Table 39) reports high percentages of risk factors present for the elbows, forearms, and hands (~ 64 %) and neck, shoulder, and upper back (~ 54 %). A few environmental and organizational modifying factors are present as well.

IIIE. MANHOLE AND HATCH ASSEMBLY

IIIE1. Manhole and Hatch Assembly Process

There are approximately three thousand manhole or hatch covers made for every vessel produced by Litton Ingalls Shipbuilding. Every manhole cover must be attached to its base by bolts or studs. These studs are attached to each plate in a process called stud welding. Stud welding permits the fastening of an assembly to a structure without piercing the metal of the structure. In manhole and hatch assembly, stud welding eliminates drilling or punching holes in a hatch or manhole plate while attaching bolts or studs to the plate. A special collet on the stud welding gun holds the stud in the nose of the gun and an electric current is passed to the stud. The fluxed end of the stud is placed in contact with the steel plate. The stud is automatically retracted from the plate surface which produces an arc. At the end of an automatically timed period, the molten end of the stud is forced against the molten metal pool on the plate resulting in the stud being securely welded to the plate.

Studs can range in size from ½-inch to 7/8-inch in diameter. A typical manhole cover has approximately 26 studs attached to it. A worker can complete about 15 to 20 covers in a day, meaning that about 400 to 500 studs are welded to hatch covers each day. The stud gun weighs approximately 12 pounds. In Figure 28, the worker is lifting the manhole plate onto the work table. In Figures 29 and 30, the worker is clamping the hatch cover to the work surface. In

Figure 31, the worker is loading a stud into the stud gun. In Figures 32 and 33, the worker is seen operating the stud gun to weld the stud onto the hatch cover. In Figure 34, the worker removes the clamps to release the hatch from the work surface.



Figure 28. Manhole Assembler Lifting Manhole Cover onto Worktable



Figure 29. Manhole Assembler Punching Holes in Hatch with Hammer



Figure 30. Manhole Assembler Re-Clamping Hatch



Figure 31. Manhole Assembler Re-Loading Stud Shooter



Figure 32. Manhole Assembler Operating Stud Shooter



Figure 33. Close-Up of Manhole Assembler Operating Stud Shooter



Figure 34. Manhole Assembler Unclamping Hatch

IIIE2. Ergonomic Risk Factors of Manhole and Hatch Assemblers

The worker must lift the manhole cover and ring onto the work surface. These pieces each weigh approximately 30 pounds. The worker is flexed over the table putting undue strain on the lower back and neck. The worker must lift the stud gun (at 12 pounds) about 400 to 500 times each day, fatiguing the upper extremity. Firing the stud gun results in exposure vibration due to impact of the stud onto the metal surface.

IIIE3. Ergonomic Analysis of Manhole and Hatch Assemblers

Using several of the exposure assessment tools outlined previously, an ergonomic analysis was performed for the manhole assemblers. A Rapid Upper Limb Assessment was conducted for the these workers (Table 40), analyzing six sub-tasks with unique postures and forces. Two of the six subtasks, removing/ replacing manhole cover and shooting studs, scored 7's (investigate and change immediately) on a scale of 1 to 7. Another subtask, un-clamping manhole, scored a 6 (investigate further and change soon). The rest of the subtasks, including punching holes with hammer, re-clamping manhole, and re-loading stud gun, scored 4's (investigate further).

A Strain Index analysis was performed for the manhole assemblers (Table 41) with the following results:

- 1) the Intensity of Exertion was rated as “Somewhat Hard” and given a multiplier score of 3 on a scale of 1 to 13
- 2) the Duration of the task was rated as 88 % of the task cycle, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
- 3) the Efforts per Minute were noted to be 11, resulting in a multiplier of 1.5 on a scale of 0.5 to 3.0
- 4) the Hand/Wrist posture was rated as “Bad,” resulting in a multiplier of 2.0 on a scale

- of 1.0 to 3.0
- 5) the Speed of Work was rated as “Fair,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
- 6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.00 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 27. An SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE. Thus, the Strain Index indicates that this task puts the manhole assemblers at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the manhole assemblers (Table 42), of the 21 possible responses, sixteen were negative and five were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the manhole assemblers (Table 43), corrective measures were suggested for all specific sub-tasks, including removing/ replacing manhole cover and shooting studs, un-clamping manhole, punching holes with hammer, re-clamping manhole, and re-loading stud gun.

The University of Michigan 3D Static Strength Prediction Program was used to analyze the manhole assembler subtask of removing/ replacing manhole cover (Table 44). Analysis of this sub-task resulted in estimated disc compression loads at the L5/S1 disc of 821 pounds, which exceeds the NIOSH Recommended Compression Limit of 770 pounds. Thus, the 3DSSP indicates that this subtask puts the worker at an increased risk of low back injury.

The PLIBEL checklist for the manhole assembler (Table 45) reports moderate percentages of risk factors present for the elbows, forearms, and hands, (~ 55 %) neck, shoulder, upper back, (~ 50 %) and low back (~ 48 %) . Several environmental and organizational modifying factors are present as well.

IV. CONTROL TECHNOLOGY

Possible interventions and control technologies are mentioned briefly here. A more detailed report of possible interventions is in preparation.

IVA. POSSIBLE INTERVENTIONS FOR ABRASIVE BLASTERS IN THE BEACH BLAST AREA

Possible interventions for the abrasive blasters in the beach blast area include adjustable racks to hold the materials to be blasted at approximately knee to waist height. This would reduce the

amount of back flexion required for the job. Racks that allow certain workpieces to be hung would also reduce the amount of material handling that the abrasive blaster is required to perform in order to blast all sides of the material.

IVB. POSSIBLE INTERVENTIONS FOR SHIPBOARD CABLE PULLERS

Possible interventions for the shipboard cable pullers include work rotation among pullers so that time spent in postures involving overhead work, kneeling, and back flexion are minimized and work practices to begin pulls in the middle of the cable rather than at the end (which requires pulling the entire length of cable in one pull). Semi-automated cable pulling systems are also commercially available and may be able to be integrated into the current manual pulling method.

IVC. POSSIBLE INTERVENTIONS FOR PIPE WELDERS IN PIPE SHOP

Possible interventions for pipe welders using positioners mainly include training to optimally set the weld positioner to provide a work height that both reduces back flexion and still enables flat welding to be performed.

IVD. POSSIBLE INTERVENTIONS FOR GRINDERS IN THE PANEL LINE ASSEMBLY AREA

Possible interventions for grinders in the panel line assembly area include adjustable lift tables to elevate the various subassemblies prior to grinding and needlegun operations to minimize back flexion. Process changes (e.g. weldable primer, more efficient and clean welding processes) to reduce the amount of required grinding may also be explored. Portable, self-contained abrasive blasting units may also be able to be used instead of manual grinding in some cases.

IVE. POSSIBLE INTERVENTIONS FOR MANHOLE ASSEMBLERS IN THE EAST SIDE FABRICATION SHOP

Possible interventions for the manhole assembler in the east side fabrication shop include an adjustable lift table to set the work height of the manhole above the waist to reduce back flexion during assembly operations. A similar table may also be used to store the manhole cover prior to assembly so that the piece is able to be lifted from a height that minimizes back flexion. Training in proper lifting techniques may also be useful.

V. CONCLUSIONS AND RECOMMENDATIONS

Five work processes at Litton Ingalls Shipbuilding were surveyed to determine the presence of risk factors associated with musculoskeletal disorders. These processes included abrasive blasting in the beach blast area, shipboard cable pulling, pipe welding in the pipe shop, panel line grinding, and manhole assembly in the east side fabrication shop. In each process, certain work elements were found to be associated with one or more factors, including excessive force, constrained or awkward postures, contact stresses, vibration, and repetitive motions.

It is suggested that further action be taken to mitigate the exposure to musculoskeletal risk factors within each of the identified tasks. The implementation of ergonomic interventions has been found to reduce the amount and severity of musculoskeletal disorders within the working population in various industries. It is suggested that ergonomic interventions may be implemented at Litton Ingalls Shipbuilding facilities to minimize hazards in the identified job tasks.

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APPENDIX

TABLES

A1. ABRASIVE BLASTING WORKER

Table 1. Abrasive Blasting Worker RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/Time: 3/20/00

Facility: Litton Ingalls

Task: Abrasive Blasting

Area/Shop: Beach Blast

RULA: Posture Sampling Results												
RULA Component	Frame # 32730 Blast matl. below knee level		Frame # 124110 Blast matl. at, above waist level		Frame # 173730 Rest Break		Frame # 211350 Blast material at knee level		Frame # 196020 Reposition body, hose, blast items		Frame # 207120 Adjust blaster	
	Spec.	RULA Score	Spec.	RULA Score	Spec.	RULA Score	Spec.	RULA Score	Spec.	RULA Score	Spec.	RULA Score
Shoulder Extension/ Flexion	sl flx	2	mod flex	3	neut	1	sl flx	2	sl flx	2	sl flx	2
Shoulder is Raised (+1)		0		1		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	flx	2	ext	1	ext	1	ext	1	neut	2
Shoulder Abduction/ Adduction	mod abd	1	neut	0	neut	0	mod abd	1	neut	0	neut	0
Shoulder Lateral/ Medial	lat	1	neut	0	neut	0	lat	1	neut	0	neut	0
Wrist Extension/ Flexion	ext	2	neut	1	neut	1	ext	2	neut	1	neut	1
Wrist Deviation	ulnar	1	rad	1	neut	0	ulnar	1	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		0		1		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		0		2		1		1

Table 1. Abrasive Blasting Worker RULA (continued)

RULA Component	Frame # 32730 Blast material below knee level		Frame # 124110 Blast material at, above waist level		Frame # 173730 Rest Break		Frame # 211350 Blast material at knee level		Frame # 196020 Reposition body, hoses, items to blasted		Frame # 207120 Adjust blaster	
	Spec.	RULA Score	Spec.	RULA Score	Spec.	RULA Score	Spec.	RULA Score	Spec.	RULA Score	Spec.	RULA Score
Neck Extension/ Flexion	sl flx	2	sl flx	2	sl flx	2	sl flx	2	neut	1	mod flx	3
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	sl flx	2	neut	1	neut	1	sl flx	2	mod flx	3	sl flx	2
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		1		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		0		1		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		2		1		2		2		1
Total RULA Score	7		6		2		3		4		3	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately												

Table 2. Abrasive Blasting Worker Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/Time: 3/20/00

Facility: Litton Ingalls

Task: Abrasive Blasting

Area/Shop: Beach Blast

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	% MS (percentage of maximal strength)	Borg Scale (Compare to Borg Cr-10 Scale)	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					6.0

Table 2. Abrasive Blasting Worker Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion $= 100 \times \frac{\text{duration of all exertions (sec)}}{\text{Total observation time (sec)}}$ $= 100 \times \frac{6223 \text{ (sec)}}{8486 \text{ (sec)}}$ $= 73$	Rating Criterion	Rating	Multiplier
	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 - 79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			2.0

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute $= \frac{\text{number of exertions}}{\text{total observation time (min)}}$ $= 92 / 141 = .65, \text{ but static so set to } 3.0$	Rating Criterion	Rating	Multiplier
	< 4	1	0.5
	4 - 8	2	1.0
	9 - 14	3	1.5
	15 - 19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			3.0

Table 2. Abrasive Blasting Worker Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	Wrist Extension <i>(Stetson et al, 1991)</i>	Wrist Flexion <i>(Stetson et al, 1991)</i>	Ulnar Deviation <i>(Stetson et al, 1991)</i>	Perceived Posture	Rating	Multiplier
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						1.5

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	Compared to MTM <i>(observed pace is divided by MTM's predicted pace and expressed as %)</i>	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	“taking one’s own time”	2	1.0
Fair	91 -100%	“normal” speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.0

Table 2. Abrasive Blasting Worker Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	Rating Criterion	Rating	Multiplier
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + = (estimate @ 4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			1.00

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
<u>6.0</u> X	<u>2.0</u> X	<u>3.0</u> X	<u>1.5</u> X	<u>1.0</u> X	<u>1.0</u>		<u>54</u>

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 3. Abrasive Blasting Worker UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/Time: 3/20/00

Facility: Litton Ingalls

Task: Abrasive Blasting

Area/Shop: Beach Blast

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?	N	
6.5 Is the tool suspended?	N	
TOTAL	15 (68%)	7 (32%)

Table 4. Abrasive Blasting Worker OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period
(~ 45 minutes)

Date/Time: 3/20/00

Facility: Litton Ingalls

Task: Abrasive Blasting

Area/Shop: Beach Blast

Risk Factor	<u>Work Phase 1</u> Blast material below knee level	<u>Work Phase 2</u> Blast material at, above waist level	<u>Work Phase 3</u> Rest Break	<u>Work Phase 4</u> Blast material at knee level	<u>Work Phase 5</u> Reposition body, hoses, items to blasted	<u>Work Phase 6</u> Adjust blaster
TOTAL Combination Posture Score	3	1	1	3	3	2
Common Posture Combinations (collapsed across work phases)						
Back	2	1	1	2		
Arms	1	1	1	1		
Legs	7	7	2	2		
Posture Repetition (% of working time)	51	23	17	9		
Back % of Working Time Score	2	1	1	1		
Arms % of Working Time Score	1	1	1	1		
Legs % of Working Time Score	1	1	1	1		
ACTION CATEGORIES: 1 = No corrective measures 2 = Corrective measures in near future 3 = Corrective measures as soon as possible 4 = Corrective measures immediately						

Table 4. Abrasive Blasting Worker OWAS (continued)

Risk Factor	<u>Work Phase1</u> Blast material below knee level	<u>Work Phase 2</u> Blast material at, above waist level	<u>Work Phase 3</u> Rest Break	<u>Work Phase 4</u> Blast material at knee level	<u>Work Phase 5</u> Repo- sition body, hoses, items to blasted	<u>Work Phase 6</u> Adjust blaster
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	1	1	2	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	7	7	2	7	7	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	2	2	1	2	2	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	36	23	17	1	14	9

Table 5. Abrasive Blasting Worker PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/Time: 3/20/00

Facility: Litton Ingalls

Task: Abrasive Blasting

Area/Shop: Beach Blast

Section I: Musculoskeletal Risk Factors					
Methods of Application:					
1) Find the injured body region, answer yes or no to corresponding questions					
2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	N	N	N	N	N
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 5. Abrasive Blasting Worker PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 5. Abrasive Blasting Worker PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	14	5	1	1	10
PERCENTAGE	53.8	45.5	12.5	12.5	47.6
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	6				
PERCENTAGE	60.0				

A2. CABLE PULLING

Table 6. Cable Pullers (2-3" diameter, horizontal pull) RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	Facility		Area/Shop		Task			
3/20/00	Litton Ingalls		Shipboard		Cable pulling (2-3", pull horizontal)			
RULA: Posture Sampling Results								
RULA Component	Frame # 102750		Frame # 104820		Frame # 103800		Frame # 65400	
	Pull cable horizontal, below knee level		Hold cable below knee level, wait for signal		Rest		Pull cable horizontal, above knee level	
	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score
Shoulder Extension/ Flexion	mod flx	3	mod flx	3	neut	1	sl flx	2
Shoulder is Raised (+1)		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	neut	2	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	mod abd	1
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	ext	2	ext	2	neut	1	neut	1
Wrist Deviation	ulnar	1	ulnar	1	ulnar	1	ulnar	1
Wrist Bent from Midline (+1)		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		1		0		1

Table 6. Cable Pullers (2-3" diameter, horizontal pull) RULA

RULA Component	Frame # 102750		Frame # 104820		Frame # 103800		Frame # 65400	
	Pull cable horizontal, below knee level		Hold cable below knee level, wait for signal		Rest		Pull cable horizontal, above knee level	
	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score
Neck Extension/ Flexion	ext	4	ext	4	neut	1	sl flx	2
Neck Twist (+1)		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0
Trunk Extension/ Flexion	hyp flx	4	hyp flx	4	neut	1	sl flx	2
Trunk Twist (+1)		0		0		0		1
Trunk Side Bend (+1)		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		1		1		1
Total RULA Score	7		6		2		4	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately								

Table 7. Cable Pullers (2-3" diameter, horizontal pull) Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	Facility	Area/Shop	Task		
3/20/00	Litton Ingalls	Shipboard	Cable pulling (2-3", pull horizontal)		
1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	% MS <i>(percentage of maximal strength)</i>	Borg Scale <i>(Compare to Borg Cr-10 Scale)</i>	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					9.0

Table 7. Cable Pullers (2-3" diameter, horizontal pull) Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion $= 100 \times \frac{\text{duration of all exertions (sec)}}{\text{Total observation time (sec)}}$ $= 100 \times \frac{164(\text{sec})}{780(\text{sec})}$ $= 21$	Rating Criterion < 10 10 - 29 30 - 49 50 - 79 > or = 80	Rating 1 2 3 4 5	Multiplier 0.5 1.0 1.5 2.0 3.0
Duration of Exertion Multiplier			1.0

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute $= \frac{\text{number of exertions}}{\text{total observation time (min)}}$ $= 82/13 = 6$	Rating Criterion < 4 4 - 8 9 - 14 15 - 19 > or = 20	Rating 1 2 3 4 5	Multiplier 0.5 1.0 1.5 2.0 3.0
Efforts per Minute Multiplier			1.0

Table 7. Cable Pullers (2-3" diameter, horizontal pull) Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	Wrist Extension <i>(Stetson et al, 1991)</i>	Wrist Flexion <i>(Stetson et al, 1991)</i>	Ulnar Deviation <i>(Stetson et al, 1991)</i>	Perceived Posture	Rating	Multiplier
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation (*estimated, based on RULAs performed)	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						2.0

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	Compared to MTM <i>(observed pace is divided by MTM's predicted pace and expressed as %)</i>	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.0

Table 7. Cable Pullers (2-3" diameter, horizontal pull) Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	Rating Criterion	Rating	Multiplier
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + = (estimate @ 4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			1.00

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/ Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
<u>9.0</u> X	<u>1.0</u> X	<u>1.0</u> X	<u>2.0</u> X	<u>1.0</u> X	<u>1.0</u>		<u>18</u>

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 8. Cable Pullers (2-3" diameter, pull horizontal) UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders, Lifshitz and Armstrong (1986)

Date/ Time	Facility	Area/Shop	Task
3/20/00	Litton Ingalls	Shipboard	Cable pulling (2-3", pull horizontal)

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	n/a	n/a
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	n/a	n/a
3.5 Can the worker be seated while performing the job?	N	Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	n/a	n/a
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	9 (64%)	5 (36%)

Table 9. Cable Pullers (2-3" diameter, horizontal pull) OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)


Date/ Time	Facility	Area/Shop	Task	
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", pull horizontal)	
Risk Factor	<u>Work Phase1</u>	<u>Work Phase 2</u>	<u>Work Phase 3</u>	<u>Work Phase 4</u>
	Pull cable horizontally, below knee level	Hold cable below knee level, wait for signal	Rest	Pull cable horizontal, above knee level
TOTAL Combination Posture Score	2	2	1	2
Common Posture Combinations (collapsed across work phases)				
Back	2	1		
Arms	1	1		
Legs	4	2		
Posture Repetition (% of working time)	28	73		
BACK % of Working Time SCORE	1	1		
ARMS % of Working Time SCORE	1	1		
LEGS % of Working Time SCORE	2	1		
ACTION CATEGORIES: 1 = no corrective measures 2 = corrective measures in the near future 3 = corrective measures as soon as possible 4 = corrective measures immediately				

Table 9. Cable Pullers (2-3" diameter, horizontal pull) OWAS (continued)

Risk Factor	<u>Work Phase1</u> Pull cable horizontally, below knee level	<u>Work Phase 2</u> Hold cable below knee level, wait for signal	<u>Work Phase 3</u> Rest	<u>Work Phase 4</u> Pull cable horizontal, above knee level
Posture				
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	1	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	4	4	2	4
Load/ Use of Force				
1 = weight or force needed is = or <10 kg (<22lbs)	2	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)				
3 = weight or force > 20 kg (>44 lbs)				
Phase Repetition				
% of working time (0,10,20,30,40,50,60,70,80,90,100)	21	4	73	3

Table 10. Cable Pullers (2-3" diameter, horizontal pull) 3DSSPP Table

3D Static Strength Prediction Program
(University of Michigan, 1997)

Date/ Time	Facility	Area/Shop	Task
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", pull horizontal)
Work Elements:		Disc Compression (lbs) @ L5/S1 (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)	
Cable Puller Pull 2-3" Cable Horizontally		133 pounds	
 <p>Estimated Load ~ 40 lbs per hand</p>			

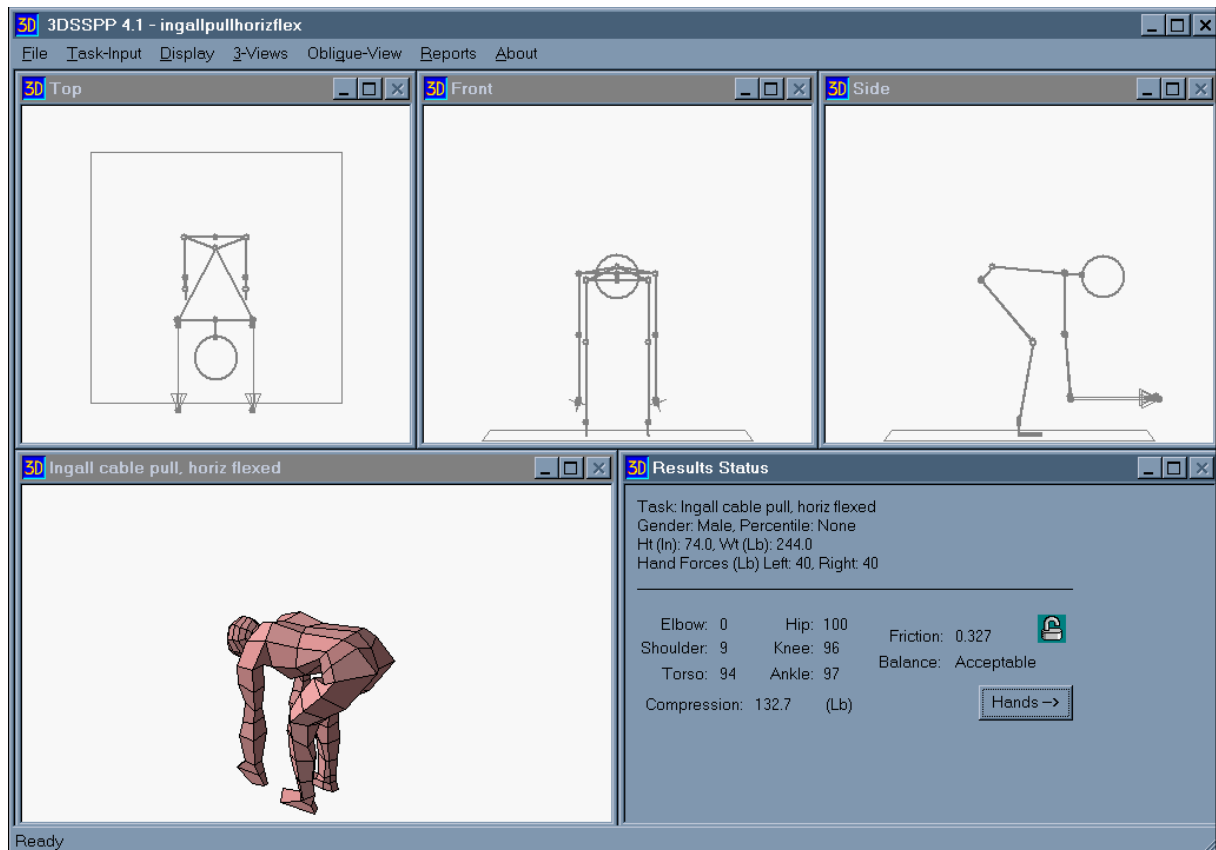


Table 11. Cable Pullers (2-3" diameter, pull horizontal) PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task		
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", pull horizontal)		
Section I: Musculoskeletal Risk Factors Methods of Application: 1) Find the injured body region, answer yes or no to corresponding questions 2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 11. Cable Pullers (2-3" diameter, pull horizontal) PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 11. Cable Pullers (2-3" diameter, pull horizontal) PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	9	4	4	10
PERCENTAGE	50	81.8	50	50	47.6
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	3				
PERCENTAGE	30.0				

Table 12. Cable pullers (1-2" diameter, overhead) RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	Facility	Area/Shop	Task			
3/20/00	Litton Ingalls	Shipboard	Cable pulling (1-2 in overhead)			
RULA: Posture Sampling Results						
RULA Component	Frame # 211650 Pull cable overhead		Frame # 203010 Rest, wait for signal		Frame # 213390 Hold cable overhead, wait for signal	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Shoulder Extension/ Flexion	hyp flex	4	hyp flex	4	hyp flex	4
Shoulder is Raised (+1)		1		1		1
Upper Arm Abducted (+1)		0		0		0
Arm supported, leaning (-1)		0		-1		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	lat	1	neut	0	neut	0
Wrist Extension/ Flexion	ext	2	neut	1	ext	2
Wrist Deviation	ulnar	1	neut	0	ulnar	1
Wrist Bent from Midline (+1)		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		0		1

Table 12. Cable pullers (1-2" diameter, overhead) RULA (continued)

RULA Component	Frame # 211650 Pull cable overhead		Frame # 203010 Rest, wait for signal		Frame # 213390 Hold cable overhead, wait for signal	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Neck Extension/ Flexion	ext	4	ext	4	sl flx	2
Neck Twist (+1)		0		0		0
Neck Side-Bent (+1)		0		0		0
Trunk Extension/ Flexion	neut	1	neut	1	neut	1
Trunk Twist (+1)		0		0		0
Trunk Side Bend (+1)		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		0		1
Total RULA Score	6		3		5	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately						

Table 13. Cable Pullers (1-2" diameter, overhead) Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	Facility	Area/Shop	Task		
3/20/00	Ingalls	Shipboard	Cable pulling (1-2 in overhead)		
1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	% MS <i>(percentage of maximal strength)</i>	Borg Scale <i>(Compare to Borg Cr-10 Scale)</i>	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					6.0

Table 13. Cable Pullers (1-2" diameter, overhead) Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
% Duration of Exertion	< 10	1	0.5
$= 100 \times \frac{\text{duration of all exertions (sec)}}{\text{Total observation time (sec)}}$ $= 100 \times \frac{141 \text{ (sec)}}{465 \text{ (sec)}}$ $= 30$	10 - 29	2	1.0
	30 - 49	3	1.5
	50 - 79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			1.5

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
Efforts per Minute	< 4	1	0.5
$= \frac{\text{number of exertions}}{\text{total observation time (min)}}$ $= 97 / 8 = 12.5$	4 - 8	2	1.0
	9 - 14	3	1.5
	15 - 19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			1.5

Table 13. Cable Pullers (1-2" diameter, overhead) Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	Wrist Extension <i>(Stetson et al, 1991)</i>	Wrist Flexion <i>(Stetson et al, 1991)</i>	Ulnar Deviation <i>(Stetson et al, 1991)</i>	Perceived Posture	Rating	Multiplier
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						2.0

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	Compared to MTM <i>(observed pace is divided by MTM's predicted pace and expressed as %)</i>	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.0

Table13. Cable Pullers (1-2" diameter, overhead) Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	Rating Criterion	Rating	Multiplier
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + = (estimate @ 4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			1.00

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/ Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
<u>6.0</u> X	<u>1.5</u> X	<u>1.5</u> X	<u>2.0</u> X	<u>1.0</u> X	<u>1.00</u>		<u>27</u>

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 14. Cable Pullers (1-2" diameter, overhead) UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

Date/ Time	Facility	Area/Shop	Task
3/20/00	Ingalls	Shipboard	Cable pull (1-2 in overhead)
* "No" responses are indicative of conditions associated with the risk of CTD's			
Risk Factors		No	Yes
1. Physical Stress			
1.1 Can the job be done without hand/ wrist contact with sharp edges		N	
1.2 Is the tool operating without vibration?			Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?			Y
1.4 Can the job be done without using gloves?			Y
2. Force			
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?		N	
2.2 Can the job be done without using finger pinch grip?			Y
3. Posture			
3.1 Can the job be done without flexion or extension of the wrist?		N	
3.2 Can the tool be used without flexion or extension of the wrist?		n/a	n/a
3.3 Can the job be done without deviating the wrist from side to side?		N	
3.4 Can the tool be used without deviating the wrist from side to side?		n/a	n/a
3.5 Can the worker be seated while performing the job?			Y
3.6 Can the job be done without "clothes wringing" motion?			Y
4. Workstation Hardware			
4.1 Can the orientation of the work surface be adjusted?		N	
4.2 Can the height of the work surface be adjusted?		N	
4.3 Can the location of the tool be adjusted?		n/a	n/a
5. Repetitiveness			
5.1 Is the cycle time longer than 30 seconds?		N	
6. Tool Design			
6.1 Are the thumb and finger slightly overlapped in a closed grip?		n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		n/a	n/a
6.3 Is the handle of the tool made from material other than metal?		n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?		n/a	n/a
6.5 Is the tool suspended?		n/a	n/a
TOTAL		7 (54%)	6 (46%)

Table 15. Cable Pullers (1-2" diameter, overhead)

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)


Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

Date/ Time	Facility	Area/Shop	Task	
3/20/00	Ingalls	Shipboard	Cable pulling (1-2 in overhead)	
Risk Factor		<u>Work Phase 1</u>	<u>Work Phase 2</u>	<u>Work Phase 3</u>
		Pull cable overhead	Rest, wait for signal	Hold cable overhead, wait for signal
TOTAL Combination Posture Score		1	1	1
Common Posture Combinations (collapsed across work phases)				
Back		1	1	1
Arms		2	2	1
Legs		1	1	1
Posture Repetition (% of working time)		22	50	6
Back % of Working Time Score		1	1	1
Arms % of Working Time Score		1	1	1
Legs % of Working Time Score		1	1	1
ACTION CATEGORIES: 1 = No corrective measures 2 = Corrective measures in near future 3 = Corrective measures as soon as possible 4 = Corrective measures immediately				

Table 15. Cable Pullers (1-2" diameter, overhead) OWAS (continued)

Risk Factor	<u>Work Phase1</u> Pull cable overhead	<u>Work Phase 2</u> Rest, wait for signal	<u>Work Phase 3</u> Hold cable overhead, wait for signal
Posture			
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	1
Arms 1 = both arms are below shoulder level 2 = one arm s at or above shoulder level 3 = both arms are at or above shoulder level	3	2	3
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1	1	1
Load/ Use of Force			
1 = weight or force needed is = or <10 kg (<22lbs)	2	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)			
3 = weight or force > 20 kg (>44 lbs)			
Phase Repetition			
% of working time (0,10,20,30,40,50,60,70,80,90,100)	16	50	6

Table 16. Cable Pullers Cable pullers (1-2" diameter, overhead) 3DSSP Table
3D Static Strength Prediction Program
(University of Michigan, 1997)

Date/ Time	Facility	Area/Shop	Task
3/20/00	Ingalls	Shipboard	<u>Cable pulling (1-2 in overhead)</u>
Work Elements:		Disc Compression (lbs) @ L5/S1 (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)	
 <p>Cable Puller Pull 1-2" Cable Overhead</p> <p>Estimated Load ~ 20 lbs per hand</p>		636 pounds	

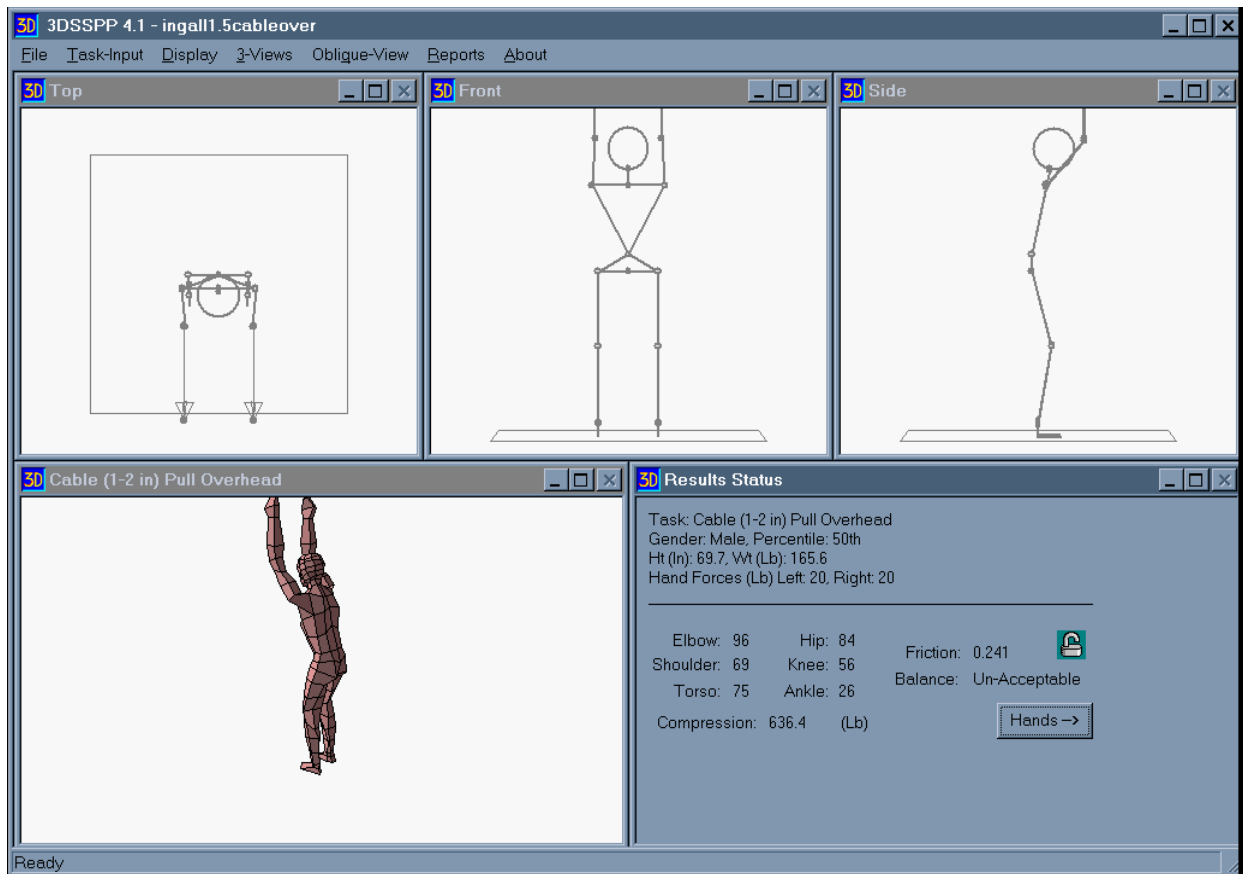


Table 17. Cable pullers (1-2" diameter, overhead) PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	Facility	Area/Shop	Task		
3/20/00	Litton Ingalls	Shipboard	Cable pulling (1-2 in overhead)		
Section I: Musculoskeletal Risk Factors Methods of Application: 1) Find the injured body region, answer yes or no to corresponding questions 2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	N				N
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 17. Cable Pullers (1-2" diameter, overhead) PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 17. Cable Pullers (1-2" diameter, overhead) PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	10	2	2	7
PERCENTAGE	50	90.9	25	25	33.3
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	3				
PERCENTAGE	30.0				

Table 18. Cable Pullers (2-3" diameter, downward pull) RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	Facility	Area/Shop	Task			
3/20/00	Litton Ingalls	Shipboard	Cable pulling (2-3", pull- down)			
RULA: Posture Sampling Results						
RULA Component	Frame # 65400		Frame # 67620		Frame # 67830	
	Pull cable down		Rest		Hold cable, wait for signal	
	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score
Shoulder Extension/ Flexion	hyp flx	4	neut	1	mod flx	3
Shoulder is Raised (+1)		1		0		0
Upper Arm Abducted (+1)		0		0		0
Arm supported, leaning (-1)		0		0		0
Elbow Extension/ Flexion	ext	1	neut	2	neut	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	ext	2	neut	1	neut	1
Wrist Deviation	ulnar	1	neut	0	ulnar	1
Wrist Bent from Midline (+1)		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		0		1

Table 18. Cable pullers (2-3" diameter, downward pull) RULA (continued)

RULA Component	Frame # 65400		Frame # 67620		Frame # 67830	
	Pull cable down		Rest		Hold cable, wait for signal	
	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score
Neck Extension/ Flexion	sl flx	2	sl flx	2	neut	1
Neck Twist (+1)		0		0		0
Neck Side-Bent (+1)		0		0		0
Trunk Extension/ Flexion	sl flx	2	neut	1	neut	1
Trunk Twist (+1)		0		0		0
Trunk Side Bend (+1)		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		1		1
Total RULA Score	7		3		4	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately						

Table 19. Cable Pullers (2-3" diameter, downward pull) Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	Facility	Area/Shop	Task		
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", pull- down)		
1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	% MS <i>(percentage of maximal strength)</i>	Borg Scale <i>(Compare to Borg Cr-10 Scale)</i>	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					13.0

Table 19. Cable Pullers (2-3" diameter, downward pull) Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
% Duration of Exertion	< 10	1	0.5
$= 100 \times \frac{\text{duration of all exertions (sec)}}{\text{Total observation time (sec)}}$ $= 100 \times \frac{140(\text{sec})}{644 (\text{sec})}$ $= 22$	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			1.0

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
Efforts per Minute	< 4	1	0.5
$= \frac{\text{number of exertions}}{\text{total observation time (min)}}$ $= 130/10.7 = 12$	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			1.5

Table 19. Cable Pullers (2-3" diameter, downward pull) Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	Wrist Extension <i>(Stetson et al, 1991)</i>	Wrist Flexion <i>(Stetson et al, 1991)</i>	Ulnar Deviation <i>(Stetson et al, 1991)</i>	Perceived Posture	Rating	Multiplier
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation (*estimated, based on RULAs performed)	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						2.0

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	Compared to MTM <i>(observed pace is divided by MTM's predicted pace and expressed as %)</i>	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.5

Table 19. Cable Pullers (2-3" diameter, downward pull) Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	Rating Criterion	Rating	Multiplier
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + = (estimate @ 4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			1.00

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/ Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
<u>13.0</u> X	<u>1.0</u> X	<u>1.5</u> X	<u>2.0</u> X	<u>1.5</u> X	<u>1.0</u>		<u>58.5</u>

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 20. Cable pullers (2-3" diameter, pull-down) UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", pull- down)

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	n/a	n/a
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	n/a	n/a
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	n/a	n/a
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	8 (57%)	5 (43%)

Table 21. Cable Pullers (2-3" diameter, downward pull) OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)


Date/ Time	Facility	Area/Shop	Task
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", pull- down)
Risk Factor	<u>Work Phase1</u>	<u>Work Phase 2</u>	<u>Work Phase 3</u>
	Pull cable down	Rest	Hold cable, wait for signal
TOTAL Combination Posture Score	3	1	1
Common Posture Combinations (collapsed across work phases)			
Back	2	1	1
Arms	2	1	2
Legs	4	2	2
Posture Repetition (% of working time)	22	63	15
BACK % of Working Time SCORE	1	1	1
ARMS % of Working Time SCORE	1	1	1
LEGS % of Working Time SCORE	2	1	1
ACTION CATEGORIES: 1 = no corrective measures 2 = corrective measures in the near future 3 = corrective measures as soon as possible 4 = corrective measures immediately			

Table 21. Cable Pullers (2-3" diameter, downward pull) OWAS (continued)

Risk Factor	<u>Work Phase1</u> Pull cable down	<u>Work Phase 2</u> Rest	<u>Work Phase 3</u> Hold cable, wait for signal
Posture			
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	2	1	2
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	4	2	2
Load/ Use of Force			
1 = weight or force needed is = or <10 kg (<22lbs)	3	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)			
3 = weight or force > 20 kg (>44 lbs)			
Phase Repetition			
% of working time (0,10,20,30,40,50,60,70,80,90,100)	22	63	15

Table 22. Cable Pullers (2-3" diameter, downward pull) 3DSSP Table

3D Static Strength Prediction Program
(University of Michigan, 1997)

Date/ Time	Facility	Area/Shop	Task
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", pull- down)
Work Elements:		Disc Compression (lbs) @ L5/S1 (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)	
 <p>Cable Puller Pull 2-3" Cable Down</p> <p>Estimated Load ~ 50 lbs per hand</p>		215 pounds	

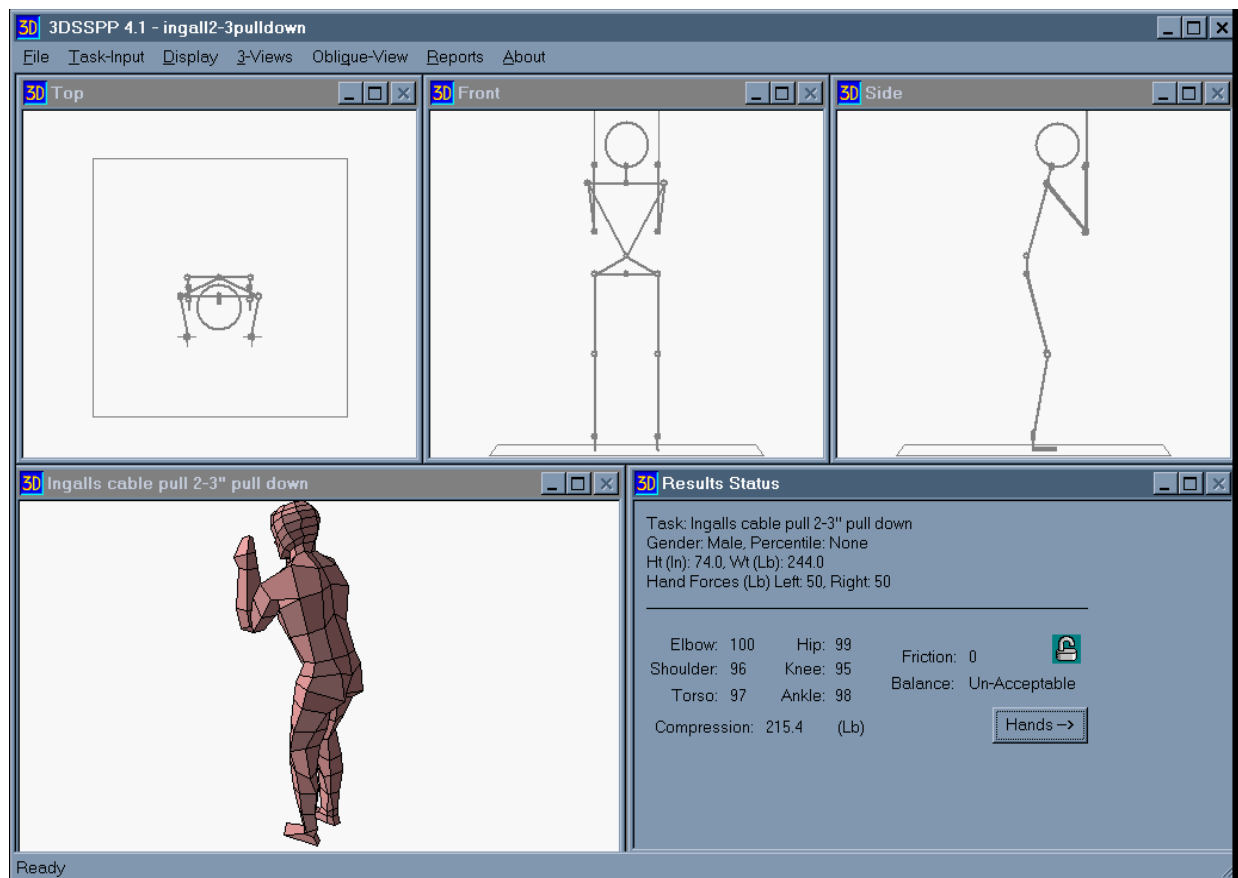


Table 23. Cable pullers (2-3" diameter, pull-down) PLIBEL
PLIBEL Checklist, Kemmlert (1995)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>		
<u>3/20/00</u>	<u>Ingalls</u>	<u>Shipboard</u>	<u>Cable pulling (2-3 in pull-down)</u>		
Section I: Musculoskeletal Risk Factors Methods of Application: 1) Find the injured body region, answer yes or no to corresponding questions 2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 23. Cable pullers (2-3" diameter, pull-down) PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 23. Cable pullers (2-3" diameter, pull-down) PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	11	7	1	1	6
PERCENTAGE	42.3	63.6	12.5	12.5	28.6
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	3				
PERCENTAGE	30.0				

Table 24. Cable Pullers (2-3" diameter, upward push) RULA

Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

<i>Date/ Time</i>	<i>Facility</i>	<i>Area/Shop</i>		<i>Task</i>		
3/20/00	Ingalls	Shipboard		Cable pulling (2-3", push-up)		
RULA: Posture Sampling Results						
RULA Component	Frame # 24630		Frame # 21150		Frame # 20640	
	Feed/ push cable upwards		Rest		Hold cable, wait for signal	
	<i>Specific</i>	<i>RULA Score</i>	<i>Specific</i>	<i>RULA Score</i>	<i>Specific</i>	<i>RULA Score</i>
Shoulder Extension/ Flexion	mod flx	3	neut	1	mod flx	3
Shoulder is Raised (+1)		1		0		1
Upper Arm Abducted (+1)		0		0		0
Arm supported, leaning (-1)		0		0		0
Elbow Extension/ Flexion	neut	2	neut	2	neut	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	flx	2	neut	1	neut	1
Wrist Deviation	ulnar	1	neut	0	neut	0
Wrist Bent from Midline (+1)		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		0		1

Table 24. Cable Pullers (2-3" diameter, upward push) RULA (continued)

RULA Component	Frame # 24630		Frame # 21150		Frame # 20640	
	Feed/ push cable upwards		Rest		Hold cable, wait for signal	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Neck Extension/ Flexion	ext	4	sl flx	2	neut	1
Neck Twist (+1)		0		0		0
Neck Side-Bent (+1)		0		0		0
Trunk Extension/ Flexion	sl flx	2	neut	1	neut	1
Trunk Twist (+1)		0		0		0
Trunk Side Bend (+1)		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		3		1		1
Total RULA Score	7		3		4	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately						

Table 25. Cable Pullers (2-3" diameter, upward push) Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	Facility	Area/Shop	Task		
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", upward push)		
1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	% MS <i>(percentage of maximal strength)</i>	Borg Scale <i>(Compare to Borg Cr-10 Scale)</i>	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					13.0

Table 25. Cable Pullers (2-3" diameter, upward push) Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
% Duration of Exertion	< 10	1	0.5
$= 100 \times \frac{\text{duration of all exertions (sec)}}{\text{Total observation time (sec)}}$ $= 100 \times \frac{170(\text{sec})}{817 (\text{sec})}$ $= 21$	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			1.0

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet:	Rating Criterion	Rating	Multiplier
Efforts per Minute	< 4	1	0.5
$= \frac{\text{number of exertions}}{\text{total observation time (min)}}$ $= 141/13.6 = 10.4$	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			1.5

Table 25. Cable Pullers (2-3" diameter, upward push) Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	Wrist Extension <i>(Stetson et al, 1991)</i>	Wrist Flexion <i>(Stetson et al, 1991)</i>	Ulnar Deviation <i>(Stetson et al, 1991)</i>	Perceived Posture	Rating	Multiplier
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation (*estimated, based on RULAs performed)	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						2.0

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	Compared to MTM <i>(observed pace is divided by MTM's predicted pace and expressed as %)</i>	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.5

Table 25. Cable Pullers (2-3" diameter, upward push) Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	Rating Criterion	Rating	Multiplier
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + = (estimate @ 4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			1.00

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/ Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
<u>13.0</u> X	<u>1.0</u> X	<u>1.5</u> X	<u>2.0</u> X	<u>1.5</u> X	<u>1.0</u>		<u>58.5</u>

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 26. Cable pullers (2-3" diameter, upward push) UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
Lifshitz and Armstrong (1986)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", push- up)

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	n/a	n/a
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	n/a	n/a
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	n/a	n/a
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	n/a	n/a
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	n/a	n/a
6.3 Is the handle of the tool made from material other than metal?	n/a	n/a
6.4 Is the weight of the tool below 4 kg (9lbs)?	n/a	n/a
6.5 Is the tool suspended?	n/a	n/a
TOTAL	8 (57%)	5 (43%)

Table 27. Cable Pullers (2-3" diameter, upward push) OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)


Date/ Time	Facility	Area/Shop	Task
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", push-up)
Risk Factor	<u>Work Phase1</u>	<u>Work Phase 2</u>	<u>Work Phase 3</u>
	Feed/ push cable upwards	Rest	Hold cable, wait for signal
TOTAL Combination Posture Score	3	1	1
Common Posture Combinations (collapsed across work phases)			
Back	2	1	1
Arms	1	1	2
Legs	4	2	2
Posture Repetition (% of working time)	21	58	21
BACK % of Working Time SCORE	1	1	1
ARMS % of Working Time SCORE	1	1	1
LEGS % of Working Time SCORE	2	1	1
ACTION CATEGORIES: 1 = no corrective measures 2 = corrective measures in the near future 3 = corrective measures as soon as possible 4 = corrective measures immediately			

Table 27. Cable Pullers (2-3" diameter, upward push) OWAS (continued)

Risk Factor	<u>Work Phase1</u> Feed/ push cable upwards	<u>Work Phase 2</u> Rest	<u>Work Phase 3</u> Hold cable, wait for signal
Posture			
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	2
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	4	2	2
Load/ Use of Force			
1 = weight or force needed is = or <10 kg (<22lbs)	3	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)			
3 = weight or force > 20 kg (>44 lbs)			
Phase Repetition			
% of working time (0,10,20,30,40,50,60,70,80,90,100)	21	58	21

Table 28. Cable Pullers (2-3" diameter, upward push) 3DSSP Table

3D Static Strength Prediction Program
(University of Michigan, 1997)

Date/ Time	Facility	Area/Shop	Task
3/20/00	Ingalls	Shipboard	Cable pulling (2-3", upward push)
Work Elements:		Disc Compression (lbs) @ L5/S1 (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)	
 <p>Cable Puller Push 2-3" Cable Upwards</p> <p>Estimated Load ~ 50 lbs per hand</p>		813 pounds	

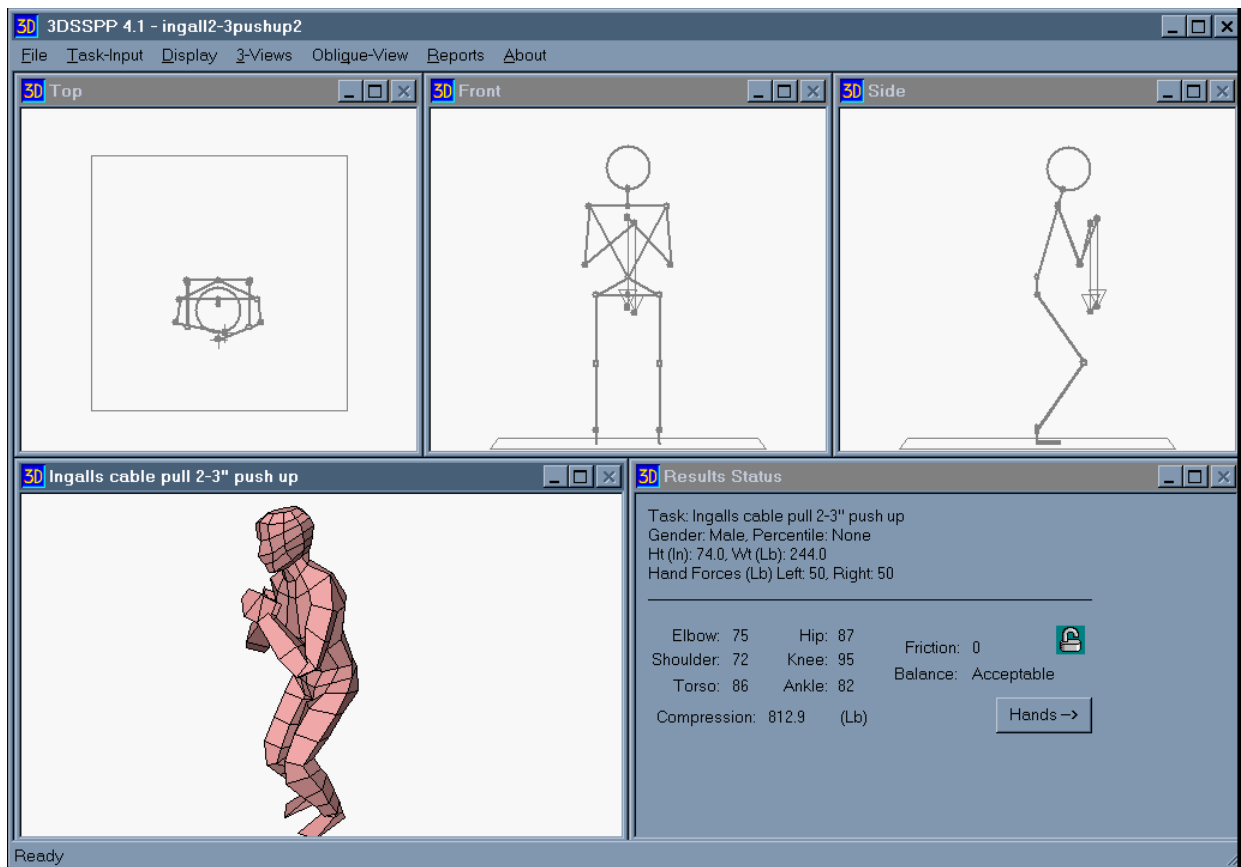


Table 29. Cable Pullers (2-3" diameter, push-up) PLIBEL

PLIBEL Checklist, Kemmlert (1995)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>		
3/20/00	Ingalls	Shipboard	Cable pulling (2-3 in push)		
Section I: Musculoskeletal Risk Factors Methods of Application: 1) Find the injured body region, answer yes or no to corresponding questions 2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 29. Cable Pullers (2-3" diameter, push-up) PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	Y				Y
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 29. Cable Pullers (2-3" diameter, push-up) PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	7	3	3	11
PERCENTAGE	50	63.6	37.5	37.5	52.4
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	Y				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	3				
PERCENTAGE	30.0				

A3. PIPE WELDER

Table 30. Pipe Welders (using positioners) RULA
Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

<i>Date/ Time</i>	<i>Facility</i>		<i>Area/Shop</i>		<i>Task</i>					
3/20/00	Ingalls		Pipe Shop		Pipe welding with positioner					
RULA: Posture Sampling Results										
RULA Component	Frame # 7590		Frame # 5040		Frame # 11130		Frame # 13680		Frame # 12390	
	Weld standing		Inspect weld		Adjust positioner		Change body positon		Get supplies	
	<i>Spec</i>	<i>RULA Score</i>	<i>Spec</i>	<i>RULA Score</i>	<i>Spec</i>	<i>RULA Score</i>	<i>Spec</i>	<i>RULA Score</i>	<i>Spec</i>	<i>RULA Score</i>
Shoulder Extension/ Flexion	sl flex	2	neut	1	mod flx	3	neut	1	neut	1
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	neut	2	neut	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	flx	2	neut	1	neut	1	neut	1	neut	1
Wrist Deviation	ulnar	1	neut	0		neut	0	neut	0	neut 0
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		0
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		1		1

Table 30. Pipe Welders (using positioners) RULA (continued)

RULA Component	Frame # 7590		Frame # 5040		Frame # 11130		Frame # 13680		Frame # 12390	
	Weld standing		Inspect weld		Adjust positioner		Change body positon		Get supplies	
	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score
Neck Extension/ Flexion	hyp flx	3	hyp flx	3	sl flx	2	sl flx	2	sl flx	2
Neck Twist (+1)		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0
Trunk Extension/ Flexion	mod flx	3	sl flx	2	neut	1	neut	1	neut	1
Trunk Twist (+1)		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		1		1
Total RULA Score	7		3		3		3		3	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately										

Table 31. Pipe Welder (using positioner) Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	Facility	Area/Shop	Task		
3/20/00	Ingalls	Pipe Shop	Pipe welding with positioner		
1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	% MS <i>(percentage of maximal strength)</i>	Borg Scale <i>(Compare to Borg Cr-10 Scale)</i>	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					3.0

Table 31. Pipe Welder (using positioner) Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion $= 100 \times \frac{\text{duration of all exertions (sec)}}{\text{Total observation time (sec)}}$ $= 100 \times \frac{201(\text{sec})}{419(\text{sec})}$ $= 48$	Rating Criterion < 10 10 - 29 30 - 49 50 -79 > or = 80	Rating 1 2 3 4 5	Multiplier 0.5 1.0 1.5 2.0 3.0
Duration of Exertion Multiplier			1.5

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute $= \frac{\text{number of exertions}}{\text{total observation time (min)}}$ $= 10/ 7 = 1.4 \text{ for welding only, but static so multiplier} = 3$	Rating Criterion < 4 4 - 8 9 -14 15 -19 > or = 20	Rating 1 2 3 4 5	Multiplier 0.5 1.0 1.5 2.0 3.0
Efforts per Minute Multiplier			3.0

Table 31. Pipe Welder (using positioner) Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	Wrist Extension <i>(Stetson et al, 1991)</i>	Wrist Flexion <i>(Stetson et al, 1991)</i>	Ulnar Deviation <i>(Stetson et al, 1991)</i>	Perceived Posture	Rating	Multiplier
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						1.5

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	Compared to MTM <i>(observed pace is divided by MTM's predicted pace and expressed as %)</i>	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.0

Table 31. Pipe Welder (using positioner) Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	Rating Criterion	Rating	Multiplier
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + = (estimate @ 4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			1.00

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/ Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
<u>3.0</u> X	<u>1.0</u> X	<u>3.0</u> X	<u>1.5</u> X	<u>1.5</u> X	<u>1.0</u>		<u>20.3</u>

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 32. Pipe Welder (using positioner) UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
 Lifshitz and Armstrong (1986)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>
3/20/00	Ingalls	Pipe Shop	Pipe welding with positioner

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?		Y
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?		Y
4.2 Can the height of the work surface be adjusted?		Y
4.3 Can the location of the tool be adjusted?	N (height)	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	8 (38%)	13 (62%)

Table 33. Pipe Welder (using positioner) OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Date/ Time	Facility	Area/Shop			Task
3/20/00	Ingalls	Pipe Shop			Pipe welding with positioner
Risk Factor	<u>Work Phase 1</u>	<u>Work Phase 2</u>	<u>Work Phase 3</u>	<u>Work Phase 4</u>	<u>Work Phase 5</u>
	Weld standing	Inspect weld	Adjust positioner	Change body position	Get supplies
TOTAL Combination Posture Score	2	2	1	1	1
Common Posture Combinations (collapsed across work phases)					
Back	2	1	1		
Arms	1	1	1		
Legs	2	2	7		
Posture Repetition (% of working time)	62	21	18		
BACK % of Working Time SCORE	2	1	1		
ARMS % of Working Time SCORE	1	1	1		
LEGS % of Working Time SCORE	1	1	1		
ACTION CATEGORIES: 1 = no corrective measures 2 = corrective measures in the near future 3 = corrective measures as soon as possible 4 = corrective measures immediately					

Table 33. Pipe Welder (using positioner) OWAS (continued)

Risk Factor	<u>Work Phase 1</u>	<u>Work Phase 2</u>	<u>Work Phase 3</u>	<u>Work Phase 4</u>	<u>Work Phase 5</u>
	Weld standing	Inspect weld	Adjust positioner	Change body positon	Get supplies
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	1	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2	2	7	7
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)					
3 = weight or force > 20 kg (>44 lbs)					
Phase Repetition					
% of working time (0,10,20,30,40,50,60,70,80,90,100)	48	14	21	14	4

Table 34. Pipe Welder (using positioner) PLIBEL

PLIBEL Checklist, Kemmlert (1995)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>		
3/20/00	Ingalls	Pipe Shop	Pipe welding with positioner		
Section I: Musculoskeletal Risk Factors Methods of Application: 1) Find the injured body region, answer yes or no to corresponding questions 2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	N	N	N	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 34. Pipe Welder (using positioner) PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	Y				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 34. Pipe Welder (using positioner) PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	10	4	0	0	4
PERCENTAGE	38.5	36.4	0	0	19
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21: Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	3				
PERCENTAGE	30.0				

A4. PANEL LINE GRINDER

Table 35. Panel Line Grinders RULA
Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

<u>Date/ Time</u>	<u>Facility</u>		<u>Area/Shop</u>		<u>Task</u>					
<u>3/20/00</u>	<u>Ingalls</u>		<u>Panel line</u>		<u>Subassembly grinding</u>					
RULA: Posture Sampling Results										
RULA Component	Frame # 71550 Grind surface		Frame # 78120 Reposition body, tool		Frame # 79170 Rest		Frame # 80040 Change tool		Frame # 81750 Needle gun	
	<i>Specific</i>	<i>RULA Score</i>	<i>Specific</i>	<i>RULA Score</i>	<i>Specific</i>	<i>RULA Score</i>	<i>Specific</i>	<i>RULA Score</i>	<i>Specific</i>	<i>RULA Score</i>
Shoulder Extension/ Flexion	mod flex	3	neut	1	neut	1	sl flx	2	mod flex	3
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	ext	1	ext	1
Shoulder Abduction/ Adduction	add	1	neut	0	neut	0	neut	0	add	1
Shoulder Lateral/ Medial	mod med	1	neut	0	neut	0	neut	0	mod med	1
Wrist Extension/ Flexion	ext	2	neut	1	neut	1	neut	1	ext	2
Wrist Deviation	ulnar	1	neut	0	neut	0	neut	0	ulnar	1
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		1
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		0		1		2

Table 35. Panel Line Grinders RULA (continued)

RULA Component	Frame # 71550 Grind surface		Frame # 78120 Reposition body, tool		Frame # 79170 Rest		Frame # 80040 Change tool		Frame # 81750 Needle gun	
	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score	Specific	RULA Score
Neck Extension/ Flexion	mod flx	3	sl flx	2	sl flx	2	sl flx	2	mod flx	3
Neck Twist (+1)		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0
Trunk Extension/ Flexion	hyp flx	4	neut	1	neut	1	sl flx	2	hyp flx	4
Trunk Twist (+1)		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		1		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		1		2
Total RULA Score	7		2		2		3		7	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately										

Table 36. Panel Line Grinders Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
 Moore and Garg, 1995

Date/ Time	Facility	Area/Shop	Task		
3/20/00	Ingalls	Panel line	Subassembly grinding		
1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	% MS <i>(percentage of maximal strength)</i>	Borg Scale <i>(Compare to Borg Cr-10 Scale)</i>	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					6.0

Table 36. Panel Line Grinders Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion $= 100 \times \frac{\text{duration of all exertions (sec)}}{\text{Total observation time (sec)}}$ $= 100 \times \frac{475 \text{ (sec)}}{813 \text{ (sec)}}$ $= 58$	Rating Criterion < 10 10 - 29 30 - 49 50 -79 > or = 80	Rating 1 2 3 4 5	Multiplier 0.5 1.0 1.5 2.0 3.0
Duration of Exertion Multiplier			2.0

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute $= \frac{\text{number of exertions}}{\text{total observation time (min)}}$ $= 44/ 14 = 3.2; \text{ *but static so set to 3.0}$	Rating Criterion < 4 4 - 8 9 -14 15 -19 > or = 20	Rating 1 2 3 4 5	Multiplier 0.5 1.0 1.5 2.0 3.0
Efforts per Minute Multiplier			3.0

Table 36. Panel Line Grinders Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	Wrist Extension <i>(Stetson et al, 1991)</i>	Wrist Flexion <i>(Stetson et al, 1991)</i>	Ulnar Deviation <i>(Stetson et al, 1991)</i>	Perceived Posture	Rating	Multiplier
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral (*estimated, based on RULAs performed)	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						1.5

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	Compared to MTM <i>(observed pace is divided by MTM's predicted pace and expressed as %)</i>	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.0

Table 36. Panel Line Grinders Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	Rating Criterion	Rating	Multiplier
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + = (estimate @ 4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			1.00

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
<u>6.0</u> X	<u>2.0</u> X	<u>3.0</u> X	<u>1.5</u> X	<u>1.0</u> X	<u>1.00</u>		<u>54</u>

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 37. Panel Line Grinders UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
 Lifshitz and Armstrong (1986)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>
3/20/00	Ingalls	Panel line	Subassembly grinding

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y (grinder)
6.3 Is the handle of the tool made from material other than metal?	N	Y
6.4 Is the weight of the tool below 4 kg (9lbs)?	N	
6.5 Is the tool suspended?	N	
TOTAL	15 (68%)	7 (32%)

Table 38. Panel Line Grinders OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Procedure: Observe workers at intervals of 30-60 seconds. Record postures and forces over a representative period (~ 45 minutes)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>			
3/20/00	Ingalls	Panel line	Subassembly grinding			
Risk Factor	<u>Work Phase1</u>	<u>Work Phase 2</u>	<u>Work Phase 3</u>	<u>Work Phase 4</u>	<u>Work Phase 5</u>	
	Grind surface	Reposition body, tool	Rest	Change tool	Needle gun	
TOTAL Combination Posture Score	3	1	1	2	3	
Common Posture Combinations (collapsed across work phases)						
Back	2	1	2			
Arms	2	1	1			
Legs	4	7	7			
Posture Repetition (% of working time)	58	37	8			
Back % of Working Time Score	2	1	1			
Arms % of Working Time Score	2	1	1			
Legs % of Working Time Score	3	1	1			
ACTION CATEGORIES: 1 = No corrective measures 2 = Corrective measures in near future 3 = Corrective measures as soon as possible 4 = Corrective measures immediately						

Table 38. Panel Line Grinders OWAS (continued)

Risk Factor	<u>Work Phase1</u> Grind surface	<u>Work Phase 2</u> Repo- sition body, tool	<u>Work Phase 3</u> Rest	<u>Work Phase 4</u> Change tool	<u>Work Phase 5</u> Needle gun
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	1	1	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	2	1	1	1	2
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	4	7	7	7	4
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs)	2	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)					
3 = weight or force > 20 kg (>44 lbs)					
Phase Repetition					
% of working time (0,10,20,30,40,50,60,70,80,90,100)	55	29	4	8	3

Table 39. Panel Line Grinders PLIBEL

PLIBEL Checklist, Kemmlert (1995)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>		
3/20/00	Ingalls	Panel line	Subassembly grinding		
Section I: Musculoskeletal Risk Factors Methods of Application: 1) Find the injured body region, answer yes or no to corresponding questions 2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 39. Panel Line Grinders PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	Y				Y
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 39. Panel Line Grinders PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	14	7	3	3	11
PERCENTAGE	53.8	63.6	37.5	37.5	52.4
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	N				
Environmental / Organizational Risk Factors Score					
SUM	3				
PERCENTAGE	30.0				

A5. MAN HOLE ASSEMBLER

Table 40. Manhole Cover Assembly RULA
Rapid Upper Limb Assessment (RULA), Matamney and Corlett (1993)

Date/ Time	Facility				Area/Shop				Task			
3/20/00	Ingalls				Hatch cover shop, east bank				Manhole Cover assembly			
RULA: Posture Sampling Results												
RULA Component	Frame # 35070 Punch holes with hammer		Frame # 35220 Un-clamp manhole		Frame # 47700 Remove/ replace manhole		Frame # 35850 Re-Clamp		Frame # 38190 Shoot studs		Frame # 40020 Load stud gun	
	Spec	RULA Score	Spec	RULA A Score	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score
Shoulder Extension/ Flexion	sl flex	2	sl flex	2	mod flx	3	sl flex	2	sl flex	2	neut	1
Shoulder is Raised (+1)		0		1		0		0		0		0
Upper Arm Abducted (+1)		0		1		1		0		1		0
Arm supported, leaning (-1)		0		0		0		0		-1		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	ext	1	neut	2	neut	2
Shoulder Abduction/ Adduction	neut	0	mod abd	1	mod abd	1	neut	0	mod abd	1	mod abd	1
Shoulder Lateral/ Medial	neut	0	mod med	1	mod med	1	neut	0	mod med	1	mod med	1
Wrist Extension/ Flexion	ext	2	ext	2	ext	2	ext	2	ext	2	neut	1
Wrist Deviation	ulnar	1	rad	1	ulnar	1	ulna r	1	ulna r	1	neut	0
Wrist Bent from Midline (+1)		0		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		1		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		1		1
Arm and Wrist Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		2		1		2		1

Table 40. Manhole Cover Assembly, RULA (continued)

RULA Component	Frame # 35070		Frame # 35220		Frame # 47700		Frame # 35850		Frame # 38190		Frame # 40020	
	Punch holes with hammer		Un-clamp manhole		Remove/ replace manhole		Re-Clamp		Shoot studs		Load stud gun	
	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score	Spec	RULA Score
Neck Extension/ Flexion	sl flx	2	sl flx	2	sl flx	2	hyp flx	3	hyp flx	3	hyp flx	3
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	mod flx	3	mod flx	3	sl flx	2	mod flx	3	hyp flx	4	neut	1
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		0		0		1		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (i.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		1		1
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		2		1		1		1
Total RULA Score	4		6		7		4		7		4	
1 or 2 = Acceptable 3 or 4 = Investigate Further 5 or 6 = Investigate Further and Change Soon 7 = Investigate and Change Immediately												

Table 41. Manhole Cover Assembler Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	Facility	Area/Shop	Task		
3/20/00	Ingalls	Hatch cover shop, east bank	Manhole Cover assembly		
1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.					
Rating Criterion	% MS <i>(percentage of maximal strength)</i>	Borg Scale <i>(Compare to Borg Cr-10 Scale)</i>	Perceived Effort	Rating	Multiplier
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					3.0

Table 41. Manhole Cover Assembler Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion $= 100 \times \frac{\text{duration of all exertions (sec)}}{\text{Total observation time (sec)}}$ $= 100 \times \frac{413(\text{sec})}{469 (\text{sec})}$ $= 88$	Rating Criterion < 10 10 - 29 30 - 49 50 -79 > or = 80	Rating 1 2 3 4 5	Multiplier 0.5 1.0 1.5 2.0 3.0
Duration of Exertion Multiplier			3.0

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute $= \frac{\text{number of exertions}}{\text{total observation time (min)}}$ $= 86/7.8 = 11$	Rating Criterion < 4 4 - 8 9 -14 15 -19 > or = 20	Rating 1 2 3 4 5	Multiplier 0.5 1.0 1.5 2.0 3.0
Efforts per Minute Multiplier			1.5

Table 41. Manhole Cover Assembler Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	Wrist Extension <i>(Stetson et al, 1991)</i>	Wrist Flexion <i>(Stetson et al, 1991)</i>	Ulnar Deviation <i>(Stetson et al, 1991)</i>	Perceived Posture	Rating	Multiplier
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	26 -40 degrees	16 - 30 degrees	16 - 20 degrees	non-neutral	3	1.5
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation (*estimated, based on RULAs performed)	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						2.0

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	Compared to MTM <i>(observed pace is divided by MTM's predicted pace and expressed as %)</i>	Perceived Speed	Rating	Multiplier
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	91 -100%	"normal" speed of motion	3	1.0
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				1.0

Table 41. Manhole Cover Assembler Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	Rating Criterion	Rating	Multiplier
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + = (worker estimates @ 5hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	4	1.00
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			1.00

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	Duration of Exertion	Efforts per Minute	Hand/ Wrist Posture	Speed of Work	Duration of Task	=	<u>SI SCORE</u>
<u>3.0</u> X	<u>3.0</u> X	<u>1.5</u> X	<u>2.0</u> X	<u>1.0</u> X	<u>1.0</u>		<u>27</u>

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:

- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 42. Manhole Cover Assembler UE CTD Checklist
Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
 Lifshitz and Armstrong (1986)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>
3/20/00	Ingalls	Hatch cover shop, east bank	Manhole Cover assembly

* "No" responses are indicative of conditions associated with the risk of CTD's

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?	N (clamps)	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N (clamps)	
6.3 Is the handle of the tool made from material other than metal?	N (clamps)	
6.4 Is the weight of the tool below 4 kg (9lbs)?	N (stud gun)	
6.5 Is the tool suspended?	N	
TOTAL	16 (76%)	5 (24%)

Table 43. Manhole Cover Assembler OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)


Date/ Time	Facility	Area/Shop		Task		
3/20/00	Ingalls	Hatch cover shop, east bank		Manhole Cover assembly		
Risk Factor	<u>Work Phase1</u>	<u>Work Phase 2</u>	<u>Work Phase 3</u>	<u>Work Phase 4</u>	<u>Work Phase 5</u>	<u>Work Phase 6</u>
	Punch holes with hammer	Un-clamp manhole	Remove/replace manhole	Re-Clamp	Shoot studs	Load stud gun
TOTAL Combination Posture Score	2	2	2	2	2	2
Common Posture Combinations (collapsed across work phases)						
Back	2	2	1			
Arms	1	1	1			
Legs	2	4	2			
Posture Repetition (% of working time)	22	35	32			
BACK % of Working Time SCORE	1	2	1			
ARMS % of Working Time SCORE	1	1	1			
LEGS % of Working Time SCORE	1	3	1			
ACTION CATEGORIES: 1 = no corrective measures 2 = corrective measures in the near future 3 = corrective measures as soon as possible 4 = corrective measures immediately						

Table 43. Manhole Cover Assembler OWAS (continued)

Risk Factor	<u>Work Phase1</u>	<u>Work Phase 2</u>	<u>Work Phase 3</u>	<u>Work Phase 4</u>	<u>Work Phase 5</u>	<u>Work Phase 6</u>
	Punch holes with hammer	Un- clamp manhole	Remove/ replace manhole	Re- Clamp	Shoot studs	Load stud gun
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	2	2	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	2	2	4	2	4	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	2	1	2	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	9	6	4	7	31	32

Table 44. Manhole Assembler 3D Static Strength Prediction Program

3D Static Strength Prediction Program
(University of Michigan, 1997)

Date/ Time	Facility	Area/Shop	Task
3/20/00	Ingalls	Hatch cover shop, east bank	Manhole Cover assembly
Work Elements: Shipboard Rigger Tilting Equipment Frame Components		Disc Compression (lbs) @ L5/S1 (Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)	
Manhole Assembler Picks Up Manhole with One Hand; Estimate Load to be ~ 40 lbs		821 pounds	
			

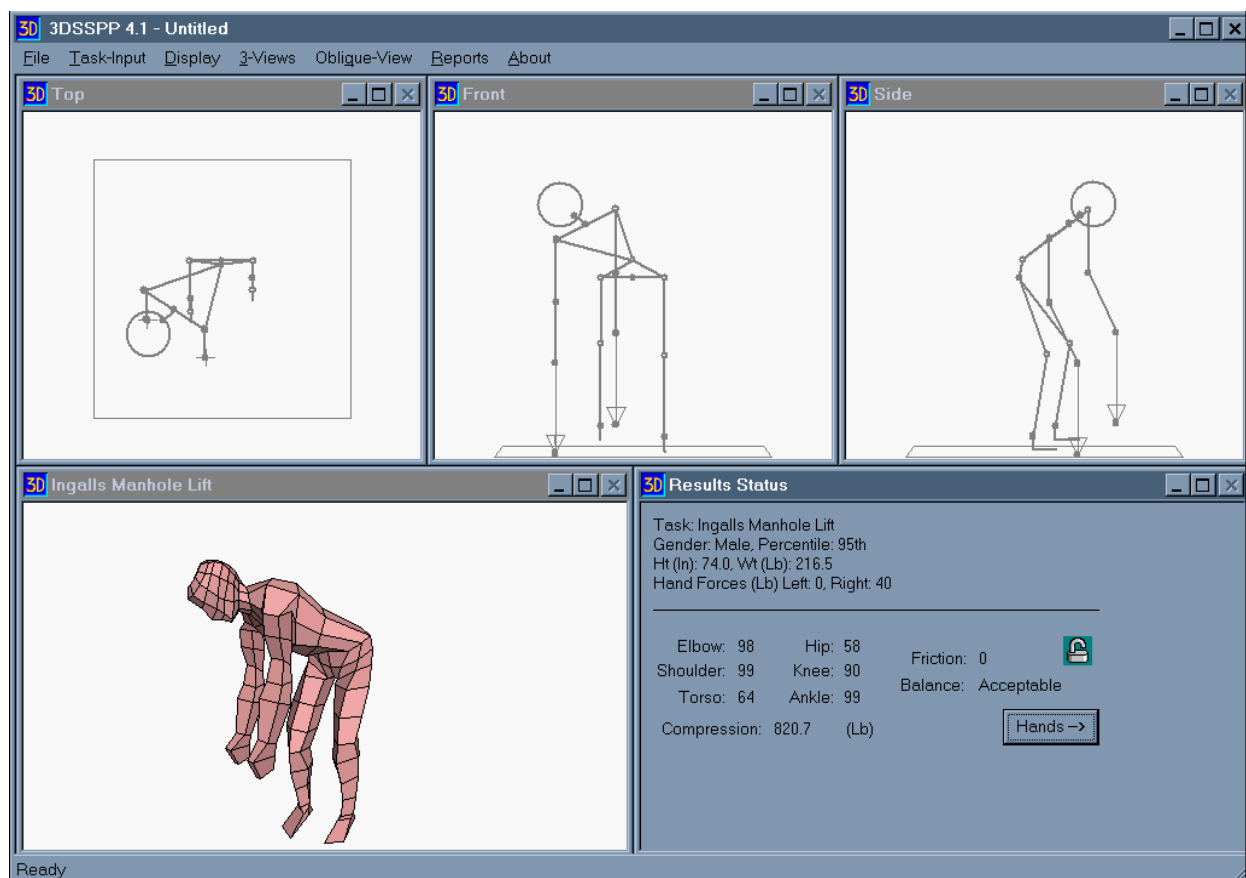


Table 45. Manhole Cover Assembler PLIBEL

PLIBEL Checklist, Kemmlert (1995)

<u>Date/ Time</u>	<u>Facility</u>	<u>Area/Shop</u>	<u>Task</u>		
3/20/00	Ingalls	Hatch cover shop, east bank	Manhole Cover assembly		
Section I: Musculoskeletal Risk Factors Methods of Application: 1) Find the injured body region, answer yes or no to corresponding questions 2) Answer questions, score potential body regions for injury risk					
Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
7: Is fatiguing foot pedal work performed?			Y	Y	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			Y	Y	Y
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			Y	Y	Y
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 45. Manhole Cover Assembler PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	Y				Y
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	N				N
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed? Notice factors of importance as:					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 45. Manhole Cover Assembler PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	13	6	2	2	10
PERCENTAGE	50	54.5	25	25	47.6
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	4				
PERCENTAGE	40.0				